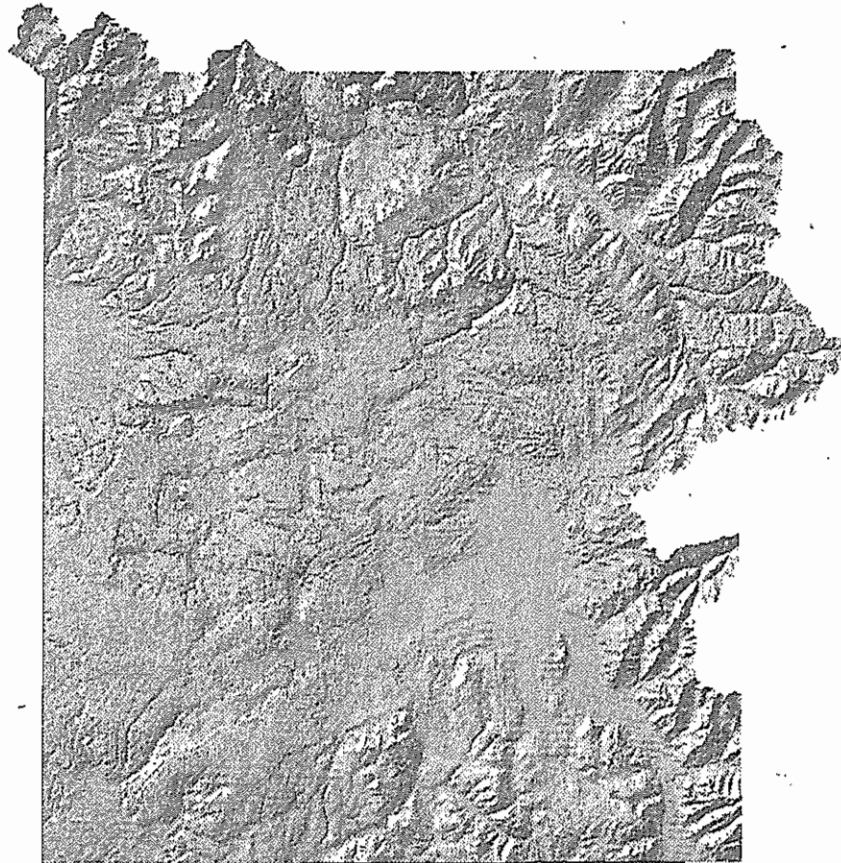


Soils of Yellowstone National Park

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This Document has been abbreviated for Web use.

The original has much more data.

1996

HOW TO USE THIS SOIL SURVEY

This survey is divided into two parts. The first part is this document, which includes an introduction, detailed descriptions of the map units, and taxonomic units, tables of information, references, a glossary, and appendices. The second part is a folder containing the detailed map sheets.

To find information about your area of interest:

- Locate the area on the Index to Map Sheets on the inside cover of this document and on the separate sheet included with the maps. Note the name of the map sheet and open up that map.
- Locate your area of interest on the map sheet. Note the map unit symbols that are in that area.
- Look up the symbols in the Index of Map Units, located at the beginning of this document. The symbols are listed alpha-numerically, followed by the number of the page where each map unit is described (Map Unit Descriptions).

The Map Unit Descriptions give detailed information about the main soils in the specified area. For more information about the range of properties of a specific soil, look up the soil name listed alphabetically in the Taxonomic Unit Descriptions. See Table of Contents for other sections of this publication that may address your specific needs.

The information on the map sheets is also available in a digital format from the Spatial Analysis Center, Yellowstone National Park, Wyoming 82190.

How to cite this soil survey.

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Major fieldwork for this soil survey was completed in 1994. Soil names and descriptions were approved in 1996. Unless otherwise indicated, statements in this publication refer to conditions in the survey area in 1989 through 1995. This survey was done cooperatively by the National Park Service and the Natural Resource Conservation Service (NRCS). The National Park Service was responsible for legend development, fieldwork, mapping methods, legend quality control, and field quality control. The Natural Resource Conservation Service was responsible for taxonomic quality control, consistency of taxonomic and map unit descriptions, and final office correlation. The document was published by the National Park Service in consultation with the Natural Resource Conservation Service.

Soil maps in this survey may be copied without permission. Enlargement of these maps, however, could cause misunderstanding of the mapping detail. If enlarged, maps do not show the small areas of contrasting soils that could have been shown at a greater resolution.

Fieldwork and computer analysis were done by: Henry F. Shovic (Party Leader), Eric Bard, Charlie Brankman, Amy Emanuelson, Susan Gregerson, Jill Harting, Alexa Calio Henry, Heidi Himmelberger, Bill Hobbs, John Lane, Bob Lindstrom, Kathy McCurdy, Dean Neprud, Ann Rodman, David Thoma, Christina Biel, Natasha Bleier, Mandi Hardy, Wendy Husk, Kristin Legg, Kathy Noaker, Jennifer Walker, and Nettie White.

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SOIL MAPS in a separate book

PURPOSE OF THE SURVEY

Yellowstone National Park is a natural laboratory for hundreds of scientific researchers from all over the world. Millions of visitors come to the park every year to view the amazing abundance of wildlife and the landscapes on which they live. Soils provide the underpinnings for those landscapes, a fact brought into focus by the fires of 1988 which underscored the need for reliable soils information. Managers, scientists, and the public were concerned about whether a new Yellowstone would rise from the ashes of hundreds of thousands of burnt over acres. New trees, shrubs, and grass grew not from ashes, but from the reservoir of seeds, bulbs, and roots protected by the nurturing soil environment. This study was commissioned to provide better information about the nature and distribution of that resource.

We undertook this study to provide baseline soil data at an Order IV level, meaning that soils are classified and mapped at a scale suitable for broad resource planning. The information can be used for site-specific work only after field verification. The map units delineate soil bodies that occur together in repeating patterns on the landscape. Rather than making map units with predetermined interpretations in mind, major soil properties were grouped to maximize differences between groups and minimize differences within a group. This type of grouping allows the user flexibility in developing interpretations for specific interests.

Soil properties affect a wide variety of seemingly unrelated phenomena. They influence the mixture of plants that spring up after a fire, partly because coarse textured soils dry more quickly than fine textured soils and may be

more susceptible to wildfire damage. Revegetation of disturbed sites is critically dependent on the preservation of the topsoil and its structure. Soils contain and protect cultural artifacts, while providing clues about the climatic environment present at the time of burial. Erosion and sedimentation are highly affected by soil type. Soils may be sediment sources, or too unstable to be used as a foundation for buildings or roads. Some soils are seasonally wet or subject to flooding, and some are shallow to bedrock. Soil properties influence ecosystem parameters, such as resistance to grazing pressure or predisposition to invasion of exotic or noxious vegetation. Medium textured soils may have a high potential for rodent activity, which affects the prey base for various species. These and many other soil properties that affect land use and potential are described in this document.

Our objectives were to provide basic soils information for use in research, resource management, and interpretive and educational purposes. Resource management planners can use it to determine the effects of different management alternatives. Research personnel can use it to plan site locations, correlate soil properties with existing information, extrapolate site data, and help place site data in a landscape context. Ecologists can better place communities of plants and animals into a landscape setting using soils as a component of the ecosystem. Wildfire personnel can use the information to predict vegetation recovery, potential wildfire soil damage, and suppression hazards. Teachers and students can study patterns of soils and how they relate to wildlife use, vegetation patterns, or visitor impact. Specialists in cultural resources, construction

and buried services can use this survey to locate which areas require more intensive field studies.

Because this document is the result of a lengthy process of scientific discovery, it includes considerable technical language. These terms are used because they have well defined and limited meanings in the discipline. Since they are not familiar to most users we have included an extensive glossary.

The location of each map unit is shown on the detailed soil maps. Each map unit and each soil in the survey area is described in detail. Help in using this publication and its digital counterpart is available from the Center for Resources, Yellowstone National Park.

This publication is a benchmark of soils knowledge within Yellowstone National Park in 1996. It will be updated to include the additional soils knowledge or the development of new management or scientific needs.

GENERAL NATURE OF THE SURVEY AREA

The survey area lies within the boundaries of Yellowstone National Park, which is located mostly in northwest Wyoming, and extends into southwest Montana and southeast Idaho (Figure 1). The survey includes 2,196,480 ac (888,915 ha). The park's physiography is primarily a set of high, forested, volcanic plateaus eroded to various degrees by glaciation and stream flow. They are flanked on the north, east, and south by mountains, but terrain to the west and southwest gradually decreases in elevation. Major mountain ranges include the Absaroka, Gallatin, and Washburn. The Continental Divide traverses the park from its southeast corner to its western boundary. The average elevation is 8,000 ft (2,479 m) and

ranges from 5,282 ft (1,637 m) in the north, where the Gardner River drains from the park to 11,358 ft (3,521 m) in the east, at the summit of Eagle Peak in the Absaroka Range.

Approximately five percent of the park is covered by water. Major rivers in the area include the Snake, Yellowstone, Gallatin, and Madison, and major lakes are Lewis, Heart, Shoshone, and Yellowstone. Yellowstone Lake lies at 7,730 ft (2,397 m) in elevation, and has an area of 136 square miles (35,259 ha) and a maximum depth of 390 ft (121 m). It is the largest lake at high elevation in North America. There are over 2,000 other lakes ranging from 0.1 ac (0.04 ha) to 7,000 ac (2,800 ha) in size.

The park environment supports seven species of coniferous trees, 1,100 species of vascular plants, and the largest concentration of large and small wild mammals in the lower 48 states. Rare mammals such as the gray wolf (reintroduction in progress), bald eagle, grizzly bear, wolverine, and pine marten make their home in the park, and rare endemic plant species such as Ross' bentgrass and Yellow-

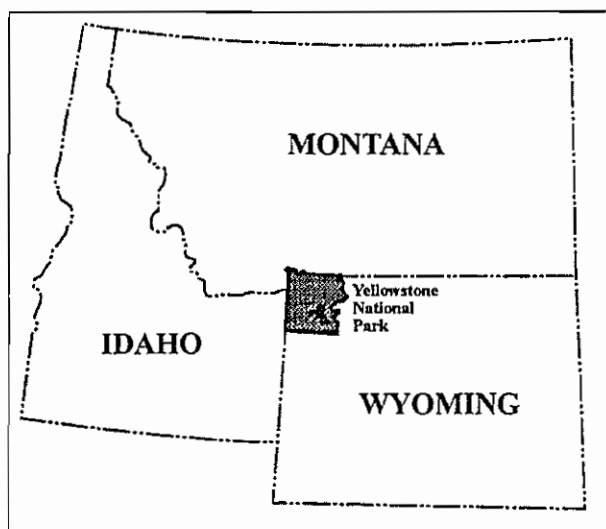


Figure 1. Location of Yellowstone in relation to Montana, Idaho, and Wyoming.

stone sand verbena are supported by its soils. Rare thermophilic microorganisms occur in hydrothermal pools and in the surrounding thermogenic soils.

Yellowstone was created as a National Park on March 1, 1872, accepted as a World Biosphere Reserve in June 1976, and as a World Heritage Site in 1978. Except for relatively small localized areas of development, most of the soils have evolved without the disturbance of human activity. Facilities in the park include restaurants, hotels, various buildings, campgrounds, 370 mi (620 km) of paved roads, 1,210 mi (2,033 km) of trails, 85 trailheads, and 300 backcountry campsites.

Soils of the survey area range from very coarse to fine textured and from very shallow to very deep. Coarse fragment content of the soil can be low to very high. Soils in the high elevation forests are usually acidic, while soils at lower elevations are neutral to alkaline. Soil temperature regimes in most of the park are cryic or frigid. Soils in hydrothermal areas can have mesic, isomesic, thermic, isothermic, hyperthermic or isohyperthermic temperature regimes.

Geology

The geologic history of the study area has been well described in a variety of publications (Keefer 1971, Parsons 1978, Harris 1980, Reid and Foote 1982). The oldest geologic materials in the park are Precambrian gneisses and schists (2.7 billion years before present), which occur in the Black Canyon of the Yellowstone River. Throughout the most of its history (2.7 to 0.6 billion years before present), the Yellowstone region has generally been under large scale tectonic compression. Subsequently, the area was eroded to a flat

plain and then flooded by large seas which deposited layers of calcium carbonate, sand, and clay up to 10,000 ft (3,050 m) thick. These Paleozoic and Mesozoic limestones, sandstones, and shales make up parent rocks of the Gallatin Range, the Red Mountains, and Mount Everts. Extensive folding and faulting has occurred in these rock units. Tectonic compression during the Laramide Orogeny (65 million years before present) formed crustal uplifts of the southern Rocky Mountains with displacement up to approximately 10,000 ft (3,050 m). Eocene Absaroka Volcanics (40 to 50 million years before present) buried the region in thick deposits of andesite lava, ash, mud, and debris flows. These deposits which make up the second most common geologic material in the park, are thousands of feet thick on its east and northwest sides. The mud and debris flows buried forests and formed the petrified or fossil forests common to the park. Isolated Tertiary flows of basalt also occur in the survey area.

The most common geologic materials are rhyolitic ash-flow tuffs and rhyolite flows, mainly of Quaternary age. Over the past two million years, thousands of cubic kilometers of rhyolite lava have been deposited on the surface. During this time, cataclysmic eruptions produced extensive sheets of rhyolitic ash flow tuff and created one of earth's largest calderas, measuring 28 x 47 mi (47 x 79 km).

The weathering products of the two main rock types (rhyolite and andesite) differ distinctly in mineral nutrient content and water-holding capacity, both factors of primary importance to soil development and plant growth. Soils therefore reflect these influences.

The Yellowstone landscape has undergone at least three extensive glaciations that have affected most of the park. Glaciers gouged mountains and valleys, creating the characteristic landforms and surficial deposits which dominate the current topography. Glacial till and glaciofluvial sediments are common throughout the park. These glaciations also left numerous glacial boulders that are prominently displayed in parts of the park, and discussed in the Appendix (see Glaciation and Erratics).

Magma under the surface provides an active heat source in parts of the park, and may contribute to the high level of seismicity in the area. This heat source gives rise to an unusually high concentration of thermal features, including geysers, hot springs, mudpots and fumaroles. Soil parent materials in these areas vary from extremely acid to basic in reaction. The weathering regime in these areas includes year-round warm temperatures and moist conditions, very different from the rest of the park. Minerals in these areas are hydrothermally altered or dissolved, and the products vary widely in composition and grain size. Unusual minerals are present in soil profiles, and the thermal regions contain unique assemblages of algae and bacteria.

Climate

The climate is characterized by long, cold winters and short cool summers (Dirks and Martner 1982, Despaign 1987). The frost-free season is less than five months at all but the lowest elevations. Frost and snowfall can occur anytime of the year at the higher elevations. Yellowstone is within the normal southward excursions of polar fronts and exposed to frequent passage of winter storm systems. Air temperatures vary from lows of

-40 through -30 degrees F to highs of 70 through 80 degrees F. The record high was 103 degrees F at Gardiner, Montana, in 1960, and the record low was -66 degrees F at West Yellowstone, Montana, in 1933, both locations at entrances to the park. Surface winds have a wide range of prevailing directions due to topography, though at higher exposed locations they are consistently from the southwest.

Average annual precipitation varies from 10 in (25.4 cm) at the north boundary to approximately 80 in (204 cm) in the southwest corner. Precipitation peaks in the park interior and large valleys during spring, and in the mountains of the northern and eastern areas during winter. Most of the park's precipitation comes as snowfall. High elevations accumulate deep snow in winter which may linger on the ground into late June. Summer precipitation is dominated by localized showers and thunderstorms. Although the park has no glaciers, permanent snowfields occur on the north sides of some high peaks.

Vegetation

Climate, wildfire patterns, and soil properties determine the distribution of vegetation within the park. Approximately 80 percent of the park is covered by forests. In general, Douglas fir forests dominate in the warm (low elevation) dry areas with medium textured soils; lodgepole pine forests dominate cool dry areas with coarse textured soils; subalpine fir and Engelmann spruce dominate in wetter areas; whitebark pine dominates the high elevation areas; and a mixture of subalpine fir and lodgepole pine cover everything else. Nonforested vegetation is most common in areas with medium and moderately fine textured soils, that weather primarily from andesite and sedimentary rock types (Despaign 1990). Willows, sedges and tufted hairgrass

dominate the wetter areas. Nonforested sites on plateaus underlain by rhyolite are typically in lake deposits or in areas of loess accumulation. Areas above 10,000 ft (3,100 m) support alpine tundra and scattered conifers.

Humans have introduced exotic plant species such as timothy, Kentucky bluegrass, and Canada thistle. Over 150 introduced species have been found, mainly restricted to road corridors, disturbed areas, and lower elevations in the northern part of the park.

The Context of the Landscape

The landscapes and soils of Yellowstone National Park fit into a larger context of associations with biotic and abiotic factors. A hierarchical system for classifying these associations has been developed (McNab and Avers 1994), based on increasing uniformity of ecological potentials. The levels of this classification are in decreasing order of size: domain, division, province, section, subsection, landtype association, landtype, and landtype phase. The park is within the "dry" domain, which includes tropical and subtropical steppes, deserts, and temperate mountainous areas. Within this domain, the park is classified in the division of "temperate steppe regime mountains." It is in the "southern Rocky mountain steppe-open woodland-coniferous forest-alpine meadow" province, and within the "yellowstone highlands" section. This section is described as a series of high plateaus resulting from ancient volcanism. Some areas are strongly glaciated, but most of the section is plateau-like. Subsections, landtype associations and landtypes have not been developed for Yellowstone National Park, but could be mapped from existing information on soils, geomorphology, vegetation, and lithology.

PREVIOUS WORK

In the first systematic investigation of soil properties completed by Trettin (1986), 67 sites were described and sampled. Extensive chemical and physical analyses are available for these sites. An erosion potential inventory was completed in 1987 for the northern third of the park and surrounding lands. This was used in the analysis of sediment sources for the Yellowstone River and provided initial information on erosive potentials of different landscapes (Shovic et al. 1988).

A general landscape map of Yellowstone National Park was completed in 1990 (Shovic, H. F., unpublished data) at a scale of 1:125,000. This map identifies general landform/regolith groups for the park. A soils investigation completed for the northwest part of the park (Shovic et al. 1991) includes a map, legend, and classification of soils in the area near Reese Creek, McMinn Bench, and Mammoth Hot Springs. This survey is at a soil family level at a scale of 1:24,000 and includes about 10,000 ac (4,000 ha). An additional analysis was completed to address issues of wildlife grazing and potential restoration of this area (Shovic 1994). Soil survey information is available for part of the area immediately surrounding Yellowstone National Park. About 30 percent of the area has adjoining soil surveys (Davis and Shovic 1984, Rodman et al. 1992, Nordin and Blackwell 1984). Soil investigations for the remainder of the surrounding area are ongoing. We used these studies to develop a perspective on the range of potential soil properties, their relationships to landscapes, and possible interpretative needs.

We concluded from this work that strong relationships exist between soils and the nature

of the regolith, landforms, and vegetation. A bedrock geology map covers the entire park at a scale of 1:125,000 (U.S. Geological Survey 1972a). Partial coverage is available at 1:62,500. Surficial geology maps are available at 1:125,000 (U.S. Geological Survey 1972b) and for most of the park's area at a scale of 1:62,500 (Pierce 1973a, 1973b, 1974a, 1974b; Richmond and Pierce 1971 1972; Richmond 1973a, 1973b, 1973c, 1973d, 1974, 1977; Richmond and Waldrop 1972, 1975; Waldrop, 1975a, 1975b; Waldrop and Pierce 1975). There are many general geological publications describing various features (e.g., Keefer 1971, Parsons 1978, Harris 1980, Reid and Foote 1982, White et. al. 1988). Some of this information is available in digital form. We used a parkwide landform/regolith map developed at a scale of 1:62,500 (Shovic 1996) and available in digital form. For vegetation characteristics we used existing habitat type and cover type maps at a scale of 1:62,500 (Despain, D., unpublished, available in digital form), which are discussed in Despain (1990).

METHODS

We produced descriptions of soils, their properties and modes of formation, and the maps of soil distribution using a set of systematic methods based on accepted scientific principles and, where needed, an extension of those principles.

Standard Soil Survey Methodology

A relatively standard set of techniques is used in soil surveys which have been developed over the many years soils have been mapped (Soil Conservation Service 1993). These techniques are based on scientific concepts of soil formation as well as pragmatic application during soil surveys. All approved soil surveys must adhere to certain quality standards. Use

of language, format, and content are consistent between surveys, yet enough flexibility is allowed to accommodate for variations in survey objectives and the intended audience.

Since soil is three dimensional, and its surface is usually covered with plant material, it is impractical to predict soil spatial patterns by direct observation. However, the soils in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil is associated with a particular segment of the landscape. By observing the soils in the survey area and relating their position to specific segments of the landscape, a soil scientist develops a concept or model of how the soils were formed. This model enables the soil scientist to predict with considerable accuracy the kind of soil at a specific location on the landscape.

Individual soils on the landscape commonly merge onto one another as their characteristics gradually change. To construct an accurate map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationships, are sufficient to verify predictions of the kinds of soil in an area and to determine boundaries between soils.

Soil scientists record the characteristics of the soil profiles they study. After describing the soils in the survey area and determining their properties, the soil scientists assign the soils to taxonomic classes or units. Taxonomic classes are concepts to classify soils systematically. Each class has a set of soil characteristics with precisely defined limits. Soil taxonomy, the

system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile.

After locating and identifying the significant combinations of soils occurring in the area, soil scientists begin to delineate them on maps. The traditional process involves transects and traverses across the landscape with field sheet in hand, drawing boundaries between combinations of soils in the field. Many soil pits are examined to verify the mapping process. Map unit descriptions are developed from notes taken during the traverse or transect process.

Yellowstone Soil Survey Methodology

The methods described above are practical where relatively detailed soil information is needed and there is reasonable access to all map unit delineations. However, access for this survey was difficult, the required level of detail was less than in agricultural or suburban areas, and the survey objectives required a more formal approach. Therefore we developed a modified set of methods for the soil survey of Yellowstone National Park.

We applied models that predicted soil properties over the landscape of an indirect input, using information gained from interpretation of aerial photographs, ground observations, and existing digital resource maps. These models were based on theories of soil development, soil-site relationships observed in the Yellowstone area, and extensive site observations of soil properties on the ground that were made over a seven-year period.

We described more than 1,100 soil profiles, their environment, and their site locations. These sites were selected as representative of the local range of important features that influence soil development and their relative extent in the park. This resulted in a random sampling of soils and a representative sample of the soil-forming conditions that occur in the park (Shovic and Montagne 1985.) Described properties include color, texture, degree and kind of soil aggregation; consistence; location and thickness of horizons; distribution of plant roots; clay films; presence of carbonates; chemical reaction (pH); and volume and character of rock fragments. All horizons have an archived box sample. Extensive site data were collected on vegetation cover, habitat type, rock types in the soil profile and on the soil surface, features relating to soil drainage, signs of disturbance, regolith characteristics, elevation, slope gradient, aspect, slope shape and position, landform, and location. All relevant data were entered into digital databases that can be linked to geographic information systems and analytical software packages.

We used these observations to make predictive models of soil occurrence on the landscape. The basic premise in these models is that the kind of soil occurring at a given location can be predicted by knowing the quantitative or qualitative values of a set of factors, i.e. the parent material from which the soil is formed, the climate and vegetation under which the soil has developed, the topography, and its age. We used the soil sample and site properties to develop and test these models. Each model is expressed in a quantitative "rule" or If-Then statement with accompanying conditions under

which it is valid. We based these conditions on the information we collected, scientific judgement, and previous research data. The rules are dynamic and easily modified as new data or analysis becomes available.

Because each factor was expressed in a digital spatial data base available in a geographic information system (GIS), the rules could be applied in a logical order to predict soils' spatial occurrence and distribution on a set of digitally produced maps. Most rule conditions were expressed in spatial data layers, though some required manual modification.

Using the GIS and the rule based system, soil maps were produced automatically during the survey process. The draft maps were used as field sheets in ground verification. Each iteration of maps represented a stage of completion. We used the GIS to flag unmapped areas (places where no rules existed for that particular combination of soil forming factors) and analyze those combinations. We resolved each case by 1) using existing sample points or taking more field samples in those areas to develop new map units, or 2) combining the areas with other map units. The process of mapping was considered complete when 1) all areas were mapped to an appropriate level of quality and detail, 2) concepts represented by the map units were logical and fit into the surrounding landscapes, and 3) map units had adequate background documentation. We edited the final draft maps using manual and computer assisted methods to match ground observations and to meet quality and readability standards. All map unit boundaries were verified on the maps using remote sensing techniques, and a sampling of each map unit was visited on the ground to verify soil occurrence and distribution.

Documentation was supported by spatial analysis using the GIS and associated data bases. We spatially referenced each sample point in a digital format. Therefore sample points could be selected within a particular delineation or based on a wide range of criteria that spatially represented any of the soil-forming factors, e.g., all sample sites in andesitic rock types, wet forest habitat types, alluvial fans, or within soil map unit 1221. We used these techniques for refinement of soil-forming concepts and for descriptions of property ranges within map unit and taxonomic unit descriptions. Each soil taxonomic unit and soil map unit has a documented set of sample sites and an associated digital data base. The conceptual basis for all delineations was also documented through the rule base. Finally, each sample site has an archived reference box sample of horizons.

Each completed draft map was overlain on a spatial model of slopes created from a digital elevation model (DEM). Slope ranges and distributions were developed and analyzed to verify accuracy of mapping, and to help describe ranges of properties.

We also matched our maps with other ongoing and completed soil surveys that border Yellowstone National Park to the extent practicable, given the differing objectives between surveys, their state of documentation, and our map unit definitions. We matched lines on the Gallatin National Forest soil survey, making the best possible correlation with our delineations and soil descriptions. However, because this survey has been completed for some time, we only changed the delineations of Yellowstone National Park map units. The Bridger Teton National Forest also has a completed survey, but it is very broadly

mapped and we did not attempt to match it. We matched the soil investigation at Grand Teton National Park (similar to that on the adjoining John D. Rockefeller Jr. Memorial Parkway), using a method similar to the one used with the Gallatin National Forest. The Targhee National Forest has an ongoing survey due to be completed in 1998. Edgematching for this area was treated slightly differently, with the objective of approaching a seamless match on our survey area boundaries. Map unit delineations were intermixed on the boundary. We used either survey's map unit descriptions depending on the best fit on the ground. Targhee National Forest map unit descriptions were used where appropriate, after converting to our map unit format.

The above analysis and documentation reflects our present conceptualization of the soils and

their distribution in Yellowstone National Park. We published the maps and documentation now to provide a benchmark of soils knowledge as of 1996. Though this publication ends an era of pedologic scientific discovery in Yellowstone National Park, the process of mapping soils here has just begun. As the needs of management and science change, this survey of soils can also change. The electronic nature of the survey provides a means for scientific and orderly updating. The digital spatial maps, physical reference samples, and accessory data bases from which the maps and descriptions came are available to provide historical data in a readily modifiable format, helping to assure the fullest possible use and greatest longevity of the information.

SOIL
MAP UNITS

INTRODUCTION

Map units are defined as the description of a combination of soils used in a soil survey (Soil Conservation Service 1993). They are the actual physical expressions of the conceptual taxons defined in the Soil Taxonomic Unit Descriptions Section. Map units include a combination of soils, mapped together to reflect the scale of mapping, standards for purity, survey objectives, and map readability.

A map unit delineation represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the soil family name or taxonomic classification (see Taxonomic Unit Descriptions) of the dominant soils or miscellaneous areas. We have defined a number of different kinds of map units. Most of our map units are soil "complexes," which are map units with two or more main soil components or miscellaneous areas in such an intricate pattern that it is not practical to map them separately at the selected scale. The pattern and proportion of the soils are somewhat similar in all areas (Soil Conservation Service 1993). There are also some "undifferentiated groups," which are map units consisting of two or more main soil components or miscellaneous areas that are not consistently associated geographically, and occur in no discernible pattern.

Each map unit delineation has at least one of the major components and may have them all. Each of the components, however need not be in every delineation. Finally, there is one "consociation," a map unit dominated by a single soil component and similar soils. The kind of map unit is identified in the map unit name at the top of the description.

Each taxonomic class has precisely defined limits for the properties of the soils. On the landscape, however, the soils and miscellaneous areas have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class can rarely, if ever, be mapped without including areas of other taxonomic classes. Consequently, each map unit is made up of the soils or miscellaneous areas for which it is named and some "included" areas that belong to other taxonomic classes.

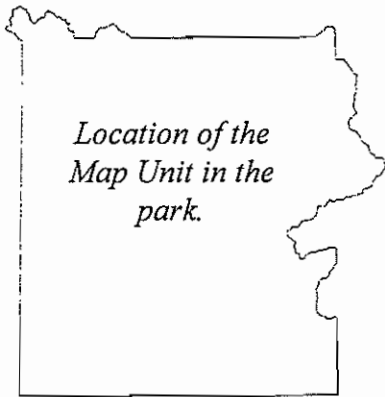
Most included soils have properties very similar to those of the dominant soil or soils in the map unit. These are called "similar inclusions." However, other included soils and miscellaneous areas, have properties and behavior divergent enough to affect use or to require different management. These are called "dissimilar inclusions." They are generally in small areas and could not be practically delineated separately at the scale of mapping. In a few areas, the pattern of soils is so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape. Therefore some soils may not have been observed and consequently are not mentioned in the descriptions. These make up a small but unavoidable part of the included soils as defined above.

The presence of included areas in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but to separate the landscape into segments that regularly occur together in a repeating pattern.

The delineation of such landscape segments on the map provides sufficient information for the development of resource plans, but if intensive use of small areas is planned, onsite investigation to precisely define and locate the soils and miscellaneous areas is needed.

A map symbol comes before the map unit name in each description. This symbol identifies soil map units on the maps. The map unit descriptions include a summary of the environment within which the soils have formed,

including landforms, slope ranges, soil parent material, and vegetation. This information is summarized in the Summary of Map Unit Characteristics Table. Knowing these characteristics helps place soils in an ecological context and aids in locating the map units on the ground. The next section, "Map Unit Format," explains the format of map unit descriptions. The Identification Legend Table gives the symbol, name, and proportionate extent of each map unit.



MAP UNIT FORMAT

MU# X Family-Y Family Complex

Summary - includes the following:

- (1) the most common landform groups within the map unit (see the Glossary for definitions of landform groups and the Landform Appendix for descriptions and oblique photographs of the main groups);
- (2) the dominant slope gradients, in percent, within the map unit (see the Slope Distribution Table for a graphical distribution of slope gradients);
- (3) the main type of

surficial geologic deposit and rock type from which the soils are forming; (4) the dominant vegetation and the most common "habitat types" within the map unit (see Habitat Type Groups Appendix for an explanation and Habitat Type Table for a list of habitat types); (5) a list of other important features, such as the presence of bedrock outcrops and soils with aquic conditions; and (6) a brief discussion of the main components and the soil properties that differentiate them.

Components

#% X family and similar inclusions (Y and Z families): *The average percent of the map unit composed of X family and soils that have properties similar to X family*

#% Dissimilar inclusions (Q family): *Soils that have properties significantly different from those of the main soil components*

Soil Description and Distribution

Soil Property Comparison

Component & Similar inclusions	Rock frag. avg. in CS (%)	Clay Avg. in CS (%)	Root-limiting layer depth (cm)	Base saturation (%)	Mollic colors avg. depth (cm)
X family Similar inclusions	#1	#2	#3	#4	#5

- #1 The weighted average (percent by volume) of rock fragments (> 2mm in diameter) within the control section.
 - #2 The weighted average of percent clay within the control section.
 - #3 The range of depths for a root-limiting layer. The ">100" means there is no root-limiting layer between the soil surface and 100 cm. This does not imply that there is a root-limiting layer at depths greater than 100 cm.
 - #4 An estimate of percent base saturation (%BS) for the whole soil calculated from a relationship between %BS and pH. This is most meaningful in a comparison between soils with similar textures and organic matter content.
 - #5 A relative number, based on depth of mollic colors, that can be used in comparisons of organic matter accumulations between different soils. Mollic colors have a value of 5 or less when dry and 3 or less when moist. They also have a chroma of 3 or less when moist.
- Similar inclusion properties - These are the range of average properties for all the similar inclusions (Y and Z families)

X family: The type of epipedon (mollic, umbric, ochric, or histic) and the presence of important layers (argillic horizons or root-limiting layers) or aquic conditions in the soil family. The range of general textural classes of the soil in this map unit. The distribution of this soil family within the map unit.

Typical Profile: Taxonomic classification (pedon #). All colors are for moist conditions.

A brief description of a typical pedon of the X family that actually occurs in this map unit. The description of each horizon includes depth, moist colors, textures, and pH values. It can also include information about aquic conditions and soil temperatures when appropriate.

Dissimilar inclusions: The properties of each inclusion that make them very different from any of the main components.

CLASSIFICATION OF THE SOILS

INTRODUCTION

Soil occurs as a thin mantle over much of Yellowstone National Park. It is a natural body, consisting of organic and mineral materials, in which plants grow. It forms a continuous system, varying from place to place. Because of this variation, the soil continuum is viewed as a collection of individual soil types, each occupying a defined segment of the soil landscape and differing from other soils by a unique set of properties.

SOIL FORMATION

Each soil is a result of soil-forming processes that act through time on mineral matter at the surface of the earth. Since these processes function over a wide range of environmental conditions, they produce soils that varies in appearance, composition, and productivity.

The factors that cause soils to vary are (1) topography and drainage; (2) physical and mineralogical composition of the parent material of the soil; (3) the climate under which the soil material has accumulated; (4) biological activity, including the plant and animal life in and on the soil; and (5) the length of time the forces of formation have acted on the soil material (Soil Survey Staff, 1975). Differences among soils depend largely on these environmental influences. Each soil is affected by all five factors, but the relative effect and importance of each varies from one soil to another.

The surficial material from which the soils have formed are among the strongest influences on the character of soils in the park. Soil formation starts with and results from changes in the parent material. The nature of the changes is strongly influenced by the character

of this parent material, particularly its mineralogy and texture. These properties affect various physical and chemical aspects of the soil-forming environment and are therefore important to essentially all processes of soil development.

Most of the parent material in the park is derived from igneous rocks, primarily rhyolite, rhyolitic tuff, and andesite with smaller amounts of basalt and granite. Rhyolite and granite are high in quartz and potassium feldspars, andesite is high in sodium plagioclase and hornblende, and basalt is high in calcium plagioclase and pyroxene. Sedimentary rock types (sandstone, shale, and limestone) and metamorphic rock types (schist and gneiss) make up the remaining bedrock sources of parent material. In general, soils weathering from shale, limestone, or schist have the highest clay content, followed by andesite, basalt, rhyolitic tuff, sandstone, granite, and rhyolite. Dark surface layers tend to be thickest in the soils forming from andesite, basalt and undifferentiated sedimentary rocks, followed by rhyolitic tuff and rhyolite.

Parent materials can be classified into three broad groups: (1) those formed from rocks weathering in place, (2) those that have been transported from their place of origin and redeposited in a new location, and (3) organic deposits. Most Yellowstone soils are formed from transported materials, including colluvium, fan alluvium, glacial till, glaciofluvial alluvium, lacustrine deposits, landslide debris, loess, and stream alluvium. Soils formed from residual materials make up approximately four percent of the park's area, and organic deposits less than one percent.

One of the park's most visible characteristics is its array of hydrothermal features. These areas create a unique and complicated soil-forming environment. Soil pH can vary from less than 3 to more than 8, and mean annual soil temperatures range from less than 10 to more than 75 degrees C. Soils forming under these conditions are very different from those that have not been affected by hydrothermal activity. Because of the unique characteristics of these soils, we have given extra attention to their properties and formation. For information about field investigations and cooperative research efforts, see Assumptions for Classification and Hydrothermal Soil Studies in the Appendices.

SOIL PROPERTIES

During the survey, over 1,000 soil pits were excavated and examined to identify and classify the soils. Soil properties were determined by field examination of the soils and by laboratory index testing of some benchmark soils. Established standard procedures were followed. These tests verify field observations, verify properties that cannot be estimated accurately by field observation, and help characterize key soils.

Estimates of soil properties given in map unit descriptions and taxonomic unit descriptions include the physical and chemical characteristics of the major layers of each soil. Some of the important ones are described below.

Andic properties.—Soils forming from volcanic ash have different properties compared to those forming from quartz grains. The weathering ash can increase a soil's water-holding capacity, phosphate retention, cation exchange capacity, and liquid limits, while lowering

plastic limits. Soils with andic properties occur along the southwestern edge of the park.

Mollic colors.—The depth of mollic colors measures the thickness of dark surface layers. It can be used, when comparing different soils, as a relative estimate of organic matter in the surface layers. Organic matter can effect soil structure, contribute plant nutrients, and increase the soil's cation exchange capacity.

Percent base saturation.—This estimate of exchangeable bases as a percent of the cation exchange capacity is used to characterize the exchangeable-ion status of the soil. Comparisons are meaningful only between soils with similar textures and organic matter contents. In general, soils with low percent base saturation have low fertility levels.

Rock fragment content.—This is a volume estimate of the particles larger than 2 mm in diameter. The volume of rock fragments in the soil affects water-holding capacity, root growth, and ease of excavation.

Root-limiting depth.—Refers to the depth at which root growth is strongly inhibited by chemical or physical restrictions (including temperature). This can limit the potential type and amount of vegetative growth. Most root-limiting layers in the park are relatively unweathered bedrock. The exception is in hydrothermal areas where root growth may also be limited by acidity, high temperatures or cemented layers.

Salts and Sodium.—High levels of salts can cause poor seed germination and plant growth. This results from limited water availability due to the high osmotic concentration of salts, or a poor physical or nutritional state due to high

levels of exchangeable sodium. A conductivity of 4 mmhos per cm or more indicates high salt concentration and more than 15 percent exchangeable sodium is considered a high level of sodium. Some of the soils between Gardiner and Mammoth in the northwestern part of the park have high levels of salts and sodium.

Texture.—Refers to the proportionate quantities of sand, silt, and clay. Most of the textures reported in this survey were estimated by tactile methods in the field. The texture of a soil partially controls its ability to transmit and store air and water, its capacity to store plant nutrients (cation exchange capacity), and its susceptibility to erosion. An estimate of clay content is often used as a quick textural comparison between different soils.

SOIL CLASSIFICATION

The system of soil classification used by the National Cooperative Soil Survey has six categories (Soil Survey Staff 1975, Soil Conservation Service 1994). Beginning with the broadest, these categories are: order, suborder, great group, subgroup, family, and series. Classification is based on soil properties directly observed in the field or laboratory, or indirectly inferred from observations made in the field or laboratory. The categories are defined in the following paragraphs.

Order.—Eleven soil orders are recognized. The differences among orders reflect the dominant soil-forming processes and the degree of soil formation. Each order is identified by a word ending in "sol." An example of a common soil order in Yellowstone National Park is Inceptisol.

Suborder.—Each order is divided into suborders primarily on the basis of properties that influence soil genesis and are important to plant growth, or properties that reflect the most important variables within the orders. The last syllable in the name of a suborder indicates the order. An example is Ochrept, where "Ochr" refers to pale colored surface horizons, and "ept" is from Inceptisol.

Great Group.—Each suborder is divided into great groups on the basis of close similarities in kind, arrangement, and degree of development of pedogenic horizons; soil moisture and temperature regimes; and base status. Each great group is identified by the name of a suborder and by a prefix that indicates a property of the soil. An example is Cryochrepts, where "Cry," referring to cryic temperature regime, is added to "ochrept," the suborder of the Inceptisols that have an ochric epipedon.

Subgroup.—Each great group has a "typic" subgroup. Other subgroups are intergrades or extragrades. The typic is the central concept of the great group; it is not necessarily the most extensive. Intergrades are transitions to other orders, suborders, or great groups. Extragrades have some properties that are not representative of the great group but do not indicate transitions to any other known kind of soil. Each subgroup is identified by one or more adjectives preceding the name of the great group. An example is Typic Cryochrept, where "Typic" identifies a subgroup that typifies the Cryochrept great group.

Family.—Families are established within a subgroup on the basis of physical and chemical properties and other characteristics that affect

management and plant growth. The properties are mostly those of horizons where there is much biological activity. Among the properties and characteristics considered are particle-size class, mineral content, temperature regime, and depth of the root zone. A family name consists of the subgroup name preceded by terms that indicate soil properties. An example is loamy-skeletal, mixed, superactive Typic Cryochrepts, where "loamy-skeletal" refers to the volume of rock fragments and texture of the soil, and "mixed, superactive" refers to the type of clay minerals and the amount of cation exchange capacity that the clay contributes to the soil.

Series Family.—The final and most detailed category is not included in soil taxonomy proper. A soil series is roughly equivalent to a species in other taxonomic systems. Because of the nature of this soil survey we use taxonomic classes at higher levels (similar to genus or family in the Linnean system). The most common level is the soil family, which is one class higher than the soil series. Taxonomic family names are quite long and detailed, so to promote ease of communication we substitute a shorter name. An example is the Shadow

family, used in this survey to represent all the loamy-skeletal, mixed, superactive Typic Cryochrepts that are deeper than 100 centimeters. Shadow is an arbitrary series name occurring within the family. It does not connote any properties of the Shadow series other than those associated with the family.

The Classification of Soils Table lists every soil taxonomic unit recognized in the survey area. The following section gives a detailed description of each taxonomic unit arranged in alphabetic order. Characteristics of the soil and the material in which it formed are identified for each unit. A pedon, a small three-dimensional area of soil typical of the unit in the survey area is described. The detailed description of each soil horizon follows soil survey standards. Many of the technical terms used in the descriptions are defined in Soil Taxonomy (Soil Survey Staff, 1975; Soil Conservation Service, 1994) or in the Glossary. Following the pedon description is a range of important characteristics of that soil within the park. The Assumptions in Classification Appendix describes the assumptions that were used to classify the soils in this survey area.

ANSEL FAMILY

The Ansel family soils have ochric epipedons, argillic horizons, and nonskeletal subsoil layers with moderately fine to medium textures. The soils are greater than 100 centimeters deep. These soils form mainly in glacial till derived from andesite, rhyolitic ash-flow tuff, or sedimentary rocks. Soils in this family most often form under the forested ABLA/VAGL and ABLA/VASC habitat types.

Taxonomic Classification: Fine-loamy, mixed, superactive Typic Cryoboralfs

Typical Pedon

Location: Northwest shore of Heart Lake, Heart Lake 7.5 minute quadrangle, Yellowstone National Park, Wyoming. UTM 540940E/4903520N. Pedon 456.

Description: (All colors are for moist conditions unless otherwise stated.)

A 0 to 10 cm; black (10YR 2/1) silt loam, light brownish gray (10YR 6/2) dry; moderate coarse granular structure; slightly hard, very friable, slightly sticky and slightly plastic; 17 percent clay; slightly acid (pH 6.5); abrupt smooth boundary.

BA 10 to 33 cm; grayish brown (10YR 5/2) very gravelly silt loam, light gray (10YR 7/1) dry; weak coarse subangular blocky structure; hard, very friable, slightly sticky and slightly plastic; 35 percent gravel; 17 percent clay; neutral (pH 6.8); clear smooth boundary.

Bt1 33 to 54 cm; brown (10YR 5/3) very gravelly loam with common medium faint redoximorphic concentrations, very pale brown (10 YR 7/1) dry; moderate coarse angular blocky structure; hard, friable, sticky and slightly plastic; 30 percent gravel and 5 percent cobbles; 23 percent clay; few distinct clay films on ped faces and lining tubular and interstitial pores; slightly acid (pH 6.4); abrupt smooth boundary.

Bt2 54 to 100 cm; brown (10YR 5/3) gravelly clay loam, light gray (10YR 7/1) dry; weak coarse angular blocky structure; very hard, very friable, sticky and plastic; 15 percent gravel; 28 percent clay; common distinct clay films on ped faces and lining tubular or interstitial pores; moderately acid (pH 6.0).

Range of Important Properties

Epipedon: These ochric epipedons either have color values or chromas too high, or they are too thin, to meet the definition of other epipedons. Color hues for the epipedon range from 5YR through 10YR. Values range from 3 through 7 dry, and from 2 through 5 moist. Chromas range from 1 through 3 moist. The most common textures are loam and silt loam. The pH ranges from 4.5 to 6.8.

Control section: The most common textures are loam, silt loam and sandy clay loam. The weighted average clay content ranges from 22 through 31 percent, and averages 26 percent. The weighted average rock fragment content ranges from 0 through 33 percent and averages 16 percent. The pH ranges from 5.0 through 7.2.

Base saturation: The range for all horizons in all pedons is 31 through 100 percent. The average for all pedons is 71 percent.

TABLES

Table 1. Summary of Soil Map Unit Characteristics

Symbol	Landforms	Parent Material	Vegetation
1267	complex of glaciofluvial plains, kames, and terraces Slope range (%): less than 15 Soil Summary: skeletal Inceptisols with coarse textures, skeletal Mollisols with coarse textures, and Inceptisols with aquic conditions	glaciofluvial alluvium derived from rhyolite or rhyolitic ash-flow tuff Wet Soils (%): 15	Forest
127	glacial trough valley bottoms, concave glaciated uplands, and rolling glaciated uplands Slope range (%): less than 30 Soil Summary: skeletal Inceptisols and skeletal Mollisols	glacial till and colluvium derived from sedimentary rocks Wet Soils (%): less than 5	Forest
1282	rolling fluvial uplands, glaciofluvial outwash plains, and a complex of glaciofluvial plains, kames and terraces Slope range (%): less than 15 Soil Summary: skeletal Inceptisols with coarse textures, skeletal Mollisols with coarse textures, and skeletal Inceptisols with dark-colored surface horizons	glaciofluvial alluvium derived from rhyolite or rhyolitic ash-flow tuff Wet Soils (%): less than 5	Forest
1324	glaciated plateaus with some rolling glaciated uplands Slope range (%): less than 20 Soil Summary: skeletal Inceptisols with coarse textures, skeletal Inceptisols with root-limiting layers and coarse textures, and skeletal Mollisols with weakly developed epipedons	glacial till and colluvium derived from rhyolitic ash-flow tuff Wet Soils (%): less than 1	Forest
1358	steep or rolling colluvial slopes, or stream breaks Slope range (%): 10 to 60 Soil Summary: skeletal Inceptisols and skeletal Inceptisols with a root-limiting layer	colluvium derived from rhyolitic ash-flow tuff. About 20 percent of the map unit is underlain by rhyolite Wet Soils (%): less than 1	Forest
1532	rolling glaciated uplands and colluvial slopes, some with high relief uplands Slope range (%): 10 to 40 Soil Summary: skeletal Inceptisols greater than 100 centimeters deep and skeletal Inceptisols less than 50 centimeters deep	glacial till, glacial rubble, and colluvium derived from dacite and granite Wet Soils (%): less than 5	Forest
1537	rolling glaciated uplands, glaciated plateaus, glacial trough bottoms, with some rolling pluvial uplands Slope range (%): less than 20 Soil Summary: skeletal Inceptisols and skeletal inceptisols with root-limiting layers	glacial till derived from rhyolitic ash-flow tuff Wet Soils (%): less than 1	Forest

LANDFORM GROUPS

The surface configuration of Yellowstone National Park is a complex continuum of slopes and surficial materials. To make some sense of this complexity, we have classified groups of slopes and materials into a set of relatively homogeneous classes called "landforms". They are based on a simplification of the classification system used in *Landforms and Associated Surficial Materials of Yellowstone National Park* (Shovic 1996).

The science of landform description, classification, delineation, and interpretation is known as applied geomorphology (Thornbury 1969). Within this science, a landform is defined as: "Any physical, recognizable form or feature of the Earth's surface, having a characteristic shape, and produced by natural causes; it includes major forms such as a plain, plateau, or mountain, and minor forms such as a hill, valley, slope, esker, or dune. Taken together, landforms make up the surface configuration of the Earth." (Gary et al. ed., 1972).

Characteristics associated with landforms are important to the formation of soils. Surface topography and subsurface materials strongly

influence soil properties. Landforms also provide an easily recognizable feature that are associated with patterns and kinds of soils, and visible from vantage points and on photographs.

This section gives an illustration and a brief description of the most common landforms. The map units associated with each landform are listed, along with the differences in their vegetation and parent materials. This will help users locate map units on the ground and provide a context for understanding relationships between soils and their associated landforms, parent materials, and vegetation.

Not all of the landforms referred to in this document are included in this section. The landforms not included are associated with thermal areas (Hydrothermal Basin, Hydrothermal Breakland, Hydrothermal Explosion Crater, Hydrothermal Rolling Upland, and Hydrothermal Valley) or with areas primarily composed of bedrock outcrops (Cirque Headwalls and Landslide Scarp). Illustrations and explanations of these landforms are given in *Landforms and Associated Surficial Materials of Yellowstone National Park* (Shovic 1996).

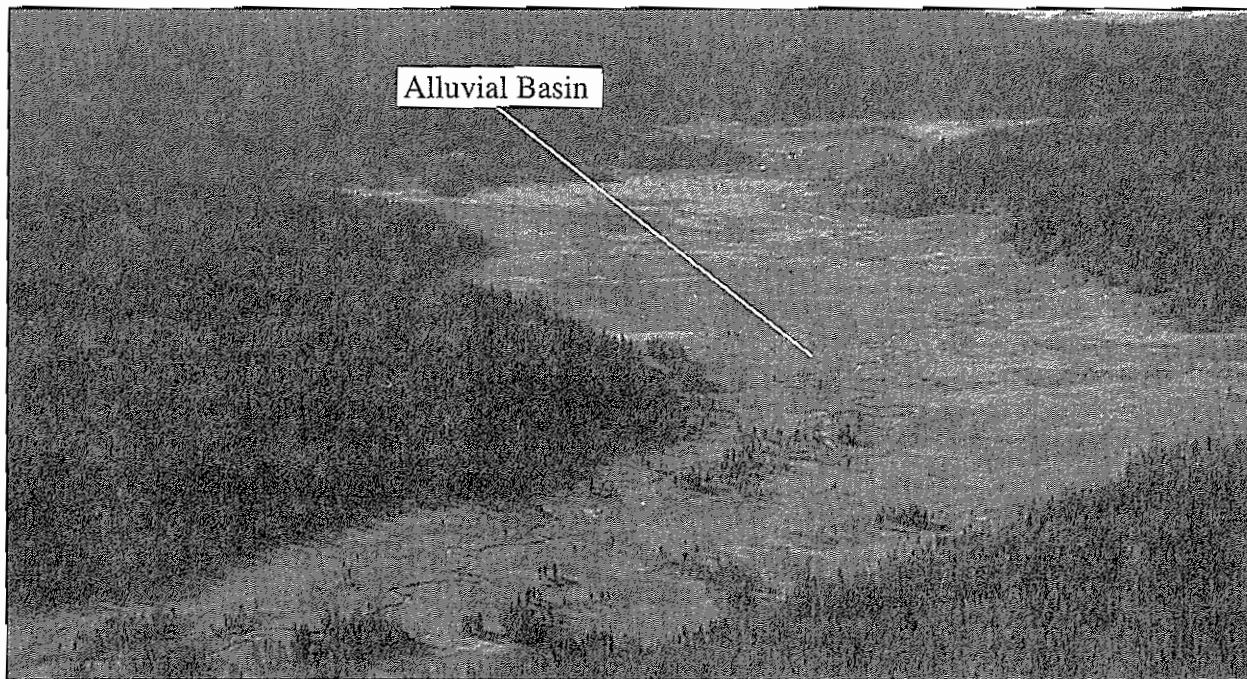


Figure 2. Alluvial Basin. An unusually broad opening in an otherwise narrow stream valley. Map unit 2662 represents this landform throughout the park.

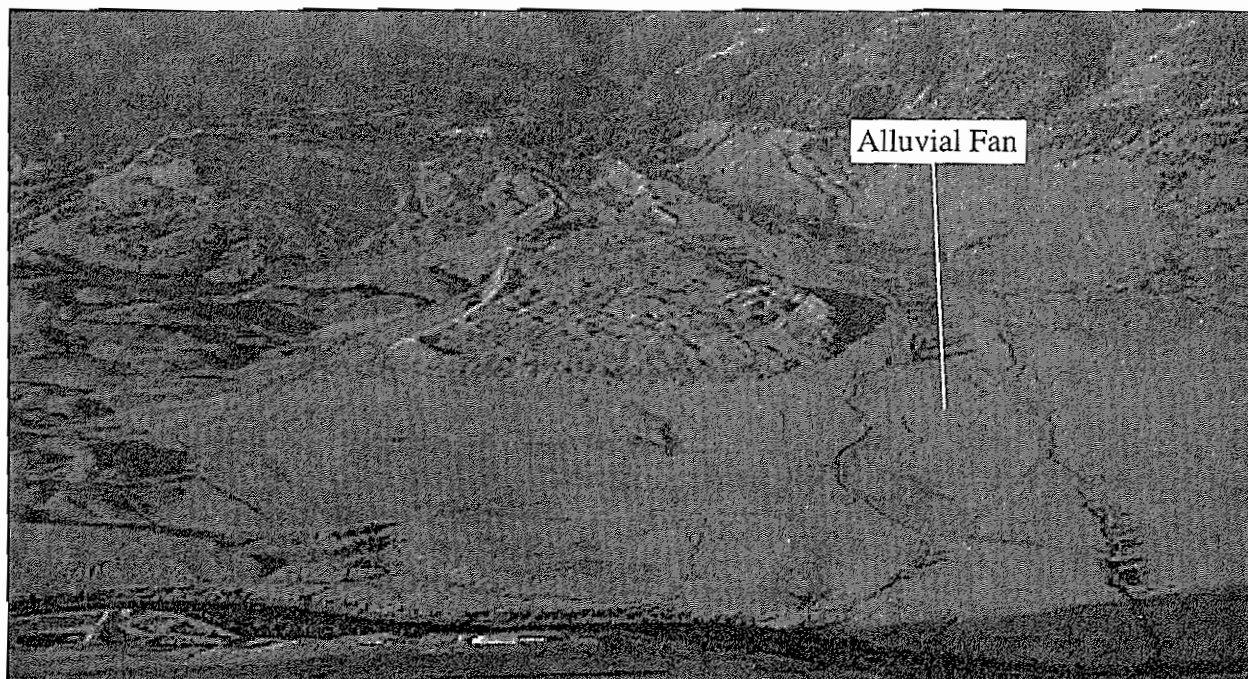


Figure 3. Alluvial Fan. The fan-like deposit of a stream where it issues from a gorge out onto a plain or of a tributary stream near or at its junction with the main stream. Map units 2222 and 1721F are nonforested and can form from a variety of rock types. Map units 2207 and 2962 are forested and form from andesite or sedimentary rocks.