United States
Department of
Agriculture

Forest Service

Pacific Southwest
Region

GEOLOGY DATA STANDARDS for ECOLOGICAL UNIT INVENTORIES for the PACIFIC SOUTHWEST REGION

R5 TECHNICAL PAPER 05-008, 1993

GEOLOGY DATA STANDARDS
for
ECOLOGICAL UNIT INVENTORIES
for the
PACIFIC SOUTHWEST REGION

Technical Contents:

Donald M. Haskins
Forest Geologist
Shasta-Trinity National Forests

John M. Chatoian
Regional Geologist
Pacific Southwest Region

Document Layout:

Gary R. Chase
Hydrologic Technician
Shasta-Trinity National Forests

Contents

I. INTRODUCTION

A. Ecological Unit Inventories

Accurate integrated resource information is needed to allow resource managers to answer complex land management questions. The emergence of Geographic Information System technology allows sophisticated integrated analyses to be performed. The goal of integrated resource inventories is to provide land managers with map and data elements that accurately merges land and vegetation into logical units with interpretations. In 1990, the Pacific Southwest Region implemented Ecological Unit Inventories, a new inventory approach to address the problems of integrating single resource inventories. Coordination during the mapping of related resources is performed by members of an interdisciplinary team. Geomorphology, bedrock geology, soil series and potential natural vegetation communities (plant associations) are mapped by specialists and integrated into one map layer. However, lines are not compromised at the expense of any resource in order assure that data and map integrity is maintained. Existing vegetation is mapped as a separate map layer. The interdisciplinary team generally maps concurrently to coordinate the delineation of common physical and interpreted boundaries, and combines them into a single map layer in order to avoid the problem of sliver polygons during GIS overlay processing.

Map units are predelineated through stereo photointerpretation of aerial photographs and each resource mapped on separate transparent overlays. Concurrent field verification by all resources is essential to refine the boundaries, collect additional data, develop relationships and make interpretations. Bedrock geology and geomorphology are mapped first and generally serve as predelineation for soil and potential natural vegetation community mapping. Soil and potential natural vegetation communities are field mapped concurrently and polygon boundary location questions resolved on site. Existing vegetation is mapped independently since boundaries are often defined by management activities, or catastrophic events.

The data collected by the each resource group conforms to National and Regional USDA Forest Service standards. When mapping is complete, polygon boundaries for the coordinated map layer is transferred from the photos to base maps utilizing a stereoscopic plotter. Resource data for both the existing vegetation and coordinated layers is entered into a relational data base and linked to the digital maps. Relationships between the layers are analyzed by querying the data base and maps may be plotted to display the results.

B. Service-Wide Data Standards

In 1989, a task force was assembled to recommend Service-wide data standards for commonly used soil, water, air and geology resource information. The task force was composed primarily of Forest Service earth science specialists, in addition to fisheries, forestry, research, land managers, range and engineering representatives. Specialists from the Soil Conservation Service and Bureau of Land Management also participated.

The task force focused on the development of a common language of earth science data terms, definitions and codes to be used for resource inventories destined for Geographic

Information System (GIS) applications. These data standards are meant to be used as the "minimum set" for resource data collection and eventual entry into a National GIS. A common language enables us to effectively share information horizontally and vertically within the Forest Service, and with other agencies and the public.

The primary objective for the task force to accomplish was to identify the set of data elements for the soil, water, air and geology resources which are widely used throughout the Agency, and for which Service-wide data standards should be developed. The following sets of data standards were identified by the Geology Group:

- ❑ Geologic Feature (Special Interest)
- ❑ Geologic Hazard
- ❑ Geologic Stratigraphy
- ❑ Geologic Structure
- ❑ Geologic Time Unit
- ❑ Groundwater Geology
- ❑ Lithologic Unit
- ❑ Mineral Resource
  - ❑ Authority for Disposal
  - ❑ Mineral Commodity
  - ❑ Activity Status
  - ❑ Mineral Deposit Model
- ❑ Topographic Feature (Geomorphology)

For each of the data sets listed above, there are data elements and definitions. The Geologic Feature data set is defined as: "a naturally occurring structure or landform which has unique significance or displays the characteristics typical of its classification". Data elements in Geologic Feature include Cave, Outcrop, Paleontological Resource, Specimen Area, Subsurface Space, Type Locality, Type Section and Unique Landform. Each of these data elements is defined and codes are proposed.

The Geologic Hazard data set includes such data elements as Avalanche Hazard, Earthquake Hazard, Expansive Soils, Floodplain, Hazardous Materials, Landslide Hazard, Subsidence and Volcanic Hazard.

The set of data elements under Geologic Stratigraphy represents a hierarchy of terms including Physiographic Province, Terrane, Group, Formation, and Member. Data Elements under Geologic Structure include Bedding, Contact, Fault, Fold Axis, Foliation, Joint and Lineation.

The Geologic Time Unit data standard is comprised of geologic Systems and Periods, with ages defined most recently by a working group from the U.S. Geological Survey.

Groundwater Geology data standards include those characteristics of subsurface water, with emphasis on the system that acts as the water-yielding hydraulic unit. Elements such as Aquifer, Recharge area and Springs are meant to address the natural system.

The Topographic data set is defined as "Any physical feature of the earth's surface having a characteristic, recognizable shape and produced by natural causes. A landform can be classified based on the process that created it and by its general shape". The Topography element is subdivided into Geomorphic Process and Landshape. Geomorphic Process elements include: Eolian, Fluvial, Glacial, Igneous, Karstification, Lacustrine, Mass Wasting, Shoreline, Surface Erosion and Tectonic. The list of Landshape data elements is quite extensive but includes a mix of landform and descriptive terms such terms as: Badlands, Bench, Butte, Crater, Cone, Fan, Saddle and Valley.

The Lithologic Unit data element set is comprised of a rock classification scheme, which is widely used by geologists, based on manner of origin, composition, and texture. This set includes both consolidated and unconsolidated earth materials.

Finally, the Mineral Resources data element is defined as: "A known or undiscovered concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible". Characterizations of the resource include: Identified, Demonstrated; Identified, Inferred; and, Undiscovered, High, Moderate, Low or Unknown Potential. Attributes of these characterizations include Authority, and Commodity and Measurement Units. Subdivisions of the Minerals Resources element include Authority for Disposal, Mineral Commodity, Activity Status, and Mineral Deposit Model.

C. <u>Region 5 Data Standards</u>

The focus of Region 5 Ecological Unit Inventories (EUI) is coordination during the mapping of related resources by members of an interdisciplinary team in order to accurately define ecological units and ecological types, which are the fundamental units of land management. Bedrock and Surficial Geology and Geomorphology maps and their related data are required components of Region 5 Ecological Unit Inventories since they are fundamental in the definition of Ecological Units and Ecological Types. Four Service-wide components, including Stratigraphy, Structure, Geologic Time and Lithologic Unit are intrinsic elements of bedrock and surficial geologic mapping. These data standards provide the basis of mapping the bedrock and surficial geology, and collecting related data. The Geomorphic Process portion of the Topographic element is the basis of the Geomorphology map.

Based on local public and management issues and concerns, Paleontology, Special Interest Areas, Groundwater and Geologic Hazards may be additional maps or attributes of Ecological Unit Inventories. The Mineral Resource Standards will not be further discussed since it is presently not an element of the EUI program, however, should be integrated in the future.

As discussed, Service-wide data standards have been proposed which are a set of standards which define the specifications for various geology data sets which must be used by all of the individual Regions, <u>if that type of data is collected</u>. The Washington Office also recognized that Regional Standards would be needed in order to provide for consistent inventories where more detailed data was required, regional issues were more specific, or where local conditions warranted different schemes.

The majority of the Service-wide Data Standards are sufficient in detail and will be used as Region 5 Geology Data Standards for Ecological Unit Inventories. Only two of the nine standards will be supplemented in Region 5 at this time; Geologic Hazard and Topography (Geomorphology).

Data Standards for Geomorphology and Geologic Hazards have evolved during the initial implementation of the EUI program. For the last several years we have worked with draft geology standards, which were tested and modified as needed. The purpose of this technical report is to present both the National and the Region 5 Geology Data Standards which will be used for the mapping of geologic resources, features and hazards in Ecological Unit Inventories. In addition, mapping concepts, including map unit design, and orders of geologic inventories will be discussed.

Finally, codes and mapping unit conventions are contained in **Appendix C** for use in both mapping and for data entry into the region 5 ecological unit inventory database/GIS link, which is an Oracle program, which resides in the Data General.

II. MAPPING CONCEPTS

A. Orders of Inventories

There are four orders of inventories recognized for geology, ranging from reconnaissance level to site-specific. The most general level of inventory is the 4th-Order inventory. This type of inventory is generally used as a reconnaissance tool for large areas, and is based on office work only. Data sources include available published literature, "in-house" information, small scale aerial photography (1:60,000), satellite imagery, and local knowledge. In most cases, the most general data standards, which are discussed in the following sections is utilized. Minimum map unit size is 160 acres, and map scales range from 1:62,500 to 1:250,000, depending on the resource issues. Examples of 4th-Order geologic inventories are maps of all areas on a Forest which have mass wasting hazards, or all areas on a Forest modified by glacial geomorphic processes, or the location of large fracture systems having potential groundwater resources. This order of inventory would serve as the basis for more intense mapping at a lower order.

An Order 3 inventory is a common one used to perform Forest-wide analyses. It is commonly used to answer Forest Planning level issues. It differs from an Order 4 inventory in data sources, field time and mapping standards. In addition to all data acquired in an Order 4 inventory, data sources include published literature and theses, unpublished reports, aerial photography having a variety of scales. More specific mapping standards, such as are discussed in the following section, are utilized. Mapping generally ranges from 4 to 10 square miles daily, on a map having a scale of 1:24,000. Minimum map unit size is approximately 10 acres and only approximately 25 percent of the units are field verified. Examples of Order 3 inventories are Forest-wide bedrock and surficial geology compilations, and Forest-wide mass wasting geomorphology and hazard maps.

An Order 2 inventory is commonly used for mapping 3rd or 4th order watersheds, or a group of contiguous watersheds less than 50,000 acres in size. This order of inventory is generally intended to address Forest project related issues. The data sources include all Order 3 and 4 data and larger scale aerial photographs, in addition to intensive field investigations, using the most specific level of data standards described in the following section. Field work is more intense, therefore, mapping rates range from 1 to 4 square miles daily, and minimum mapping unit size is 0.5 acres. Approximately 75 percent of the mapping units are field verified, and exploration pits are commonly used. Map scale varies from 1:12,000 to 1:24,000, depending on size of units and management issues. Examples of Order 2 inventories include detailed geomorphic maps, refined bedrock maps, project mass wasting hazard analyses, and ski area avalanche hazard analyses.

An Order 1 inventory is generally used for on-site investigations, where small land areas are involved and investigations are intense. Data sources include exploration pits, drilling, laboratory and field testing, including geophysics. Very large scale photographs are commonly used, ranging from 1:3,000 to 1:6,000. Map scale can be on the order of 1" = 20' to 1" = 100'. Examples of Order 1 inventories include groundwater well investigations, sewage disposal investigations, facility foundation investigations, bridge site investigations, small hydroelectric project investigations and landslide stabilization projects.

B. Map Units

The map unit concept shall be used in the mapping of geomorphology. This concept parallels that employed by soil scientists. The reason for using map unit concepts is for geologists to define their geomorphic units in a manner which is somewhat similar to that employed by the soil scientist, therefore, providing a means to consistently define similar soil/geology units. In addition, a legend has been set up for the geomorphology which is connotative in nature; a method allowing for primary and secondary definition of a mapping unit.

A map unit is a collection of areas defined and named the same in terms of their geomorphology. Each map unit differs in some respect from all other areas in a survey area and is uniquely identified in the legend. Map units may consist dominantly of one component or of two or more components which are identified in the numerical representation of the map unit. Components of minor extent not identified in the name of the map unit are inclusions. All components, whether dominant or inclusions, that are identified as important to the interpretation or understanding of the map unit are described in the map unit description.

When designing map units, it is important that each map unit meets the following criteria:

1) Can the map unit be mapped consistently, and
2) Is it needed to meet the objectives of the survey.

Does the map unit occur enough to warrant distinction and is the geomorphology being split too finely. These questions need to be answered in order to validate the necessity for each unit.

There are several different types of map units. Consociations are map units which delineate a single geomorphic process. In soils, they allow for up to 15 percent of another type or inclusion, as long as it is not too dissimilar, and the interpretation for the unit would not be adversely affected. Consociations are identified by a single alphanumeric code (**see Appendix A**).

Complexes and associations consist of two or more dissimilar geomorphic components occurring in a regularly repeating pattern where each component comprises greater than 15 percent of the map unit. The distinction between complexes and associations is a function of scale. The major components of a complex cannot be mapped separately at a scale of 1:24,000, while the major components of associations can be at that scale. Complexes and associations are identified by geomorphology codes of up to three components, separated by a slash (**see Appendix A**).

III. SERVICE-WIDE AND REGION 5 GEOLOGY DATA STANDARDS

The following section will detail the Service-wide and Region 5 geology data standards for each of the data elements.

A. Geologic Feature (Special Interest)

1. Service-Wide Data Standard

a. *Definition:*

A naturally occurring structure, outcrop, or landform which has unique significance, prominence, or displays the characteristics typical of its classification.

b. *Types:*

Cave—A naturally occurring void, cavity, recess, or system of interconnected passages beneath the surface of the earth or within a cliff or ledge, and which is large enough to permit an individual to enter, whether or not the entrance is naturally formed or constructed. (See proposed 36 CFR 290 for criteria for "significant" cave)

Outcrop—Surface exposure of a geologic formation over an area large enough to permit scientific investigation

Paleontological Resource (Fossil) Collection Area—Near-surface or surface exposure where the remains, traces, or imprints of plants or animals have been preserved in the Earth's crust (see 36 CFR 261.2). Fossil areas may be subdivided as follows:

- Invertebrate Fossil—Remains, including casts and molds, of animals without backbones and not classed as a microfossil.
- Microfossil—Remains of organisms that are too small to be studied without the aid of a microscope.
- Petrified Wood—Material formed by the replacement of the wood by silica in such a manner that the original form and structure is preserved.
- Plant Fossil—Remains of members of the plant kingdom, excluding petrified wood and microfossils.
- Trace—Indirect evidence of life, such as tracks, trails, burrows, and coprolites.
- Vertebrate Fossil—Remains, including casts and molds, of animals with skulls and internal skeletons.

Specimen Area—Surface exposure of collectable samples of semiprecious gemstones, rocks, or other mineral specimens.

Subsurface Space—An underground site, including pore space and man-made openings, of sufficient size and characteristics to be desirable as storage or for other activities requiring a controlled environment.

Type Section—The location of the originally described sequence of strata that constitute a stratigraphic unit (See "Geologic Stratigraphy"); serves as an objective standard to which spatially separated parts of the unit may be compared.

Unique Landform—a geomorphic feature which exhibits an unusual combination of well-developed components and is relatively undisturbed. Examples of features (See "Topographic Features") that may be considered unique are dunes, escarpments, gorges, waterfalls, glacial remnants, and volcanic features.

c. *Measurements:*
Usually acres, where size of area is important. Some linear features such as cave passageways may be measured in feet.

d. *Example:*
Mendenhall Glacier; Mt. St. Helens National Volcanic Monument.

e. *Source for Data Standards:*
Bates, R.L., Jackson, J.A., 1987.

2. Region 5 Data Standard

In the interim period, Region 5 will adopt the Service-wide data standards for Geologic Special Interest Areas.

B. Geologic Hazard

1. Service-Wide Data Standards

a. *Definition:*
A natural or human caused condition that poses a risk to human health or safety or which may have an adverse impact on other resource values or property.

b. *Types:*
Avalanche Hazard—Areas subject to the effects of avalanches, including initiation sites, tracks, and runout areas.

Seismic Hazard (Surface Rupture)—Zone with risk of ground rupture from a seismic event.

Seismic Hazard (Shaking)—Zone with risk of intense ground shaking, tsunami, or seiches from a seismic event.

Expansive Soils—Area underlain by soils that change volume with change in water content thereby creating structural problems.

Flood Hazard—Area within 100 year floodplain.

GeoHazardous Materials—Naturally occurring formations which contain radioactive materials, release radon gas, or are rich in asbestiform minerals.

Hazardous Workings—Abandoned mine sites (see "Mineral Resource-Activity Status") which have unprotected safety hazards such as high walls or open shafts.

Landslide Hazard—Area susceptible to mass wasting (the dislodgement and downslope movement of soil and rock material).

Subsidence—Area susceptible to sinking or settling due to being underlain by underground mining, subjected to extensive shallow pumping, or within karst topography.

Volcanic Hazard—Zone with risk from lava flows, ash or mud flows, clastic debris, or blast.

c. *Measurements:*
Area in acres

d. *Example:*
N/A

e. *Source for Data Standards:*
Hays, W. W., 1981.

2. Region 5 Data Standard

If management or public issues warrant, applicable portions of this element should be completed during Ecological Unit Inventories. Some of the geologic hazard types, defined by the Service-wide standards are modified based on Regional and Forest Issues. For others, the Service-wide standard will be retained for Regional use.

a. *Avalanche Hazard*
INTERIM STANDARD: Define snow avalanche hazard zones based on field evidence, including slope morphology, debris deposits, vegetation age and scarring. Differentiate annual hazard zones from moderate and low frequency hazard zones. Develop documentation of methodology in FY94. In the interim, define as follows

INTERPRETATION	CODE
Areas within Annual Recurrence Zone	AH
Areas within 50 year Recurrence Zone	50H
Areas within 100 year Recurrence Zone	100H
Areas outside of any avalance Zone	(NULL)

b. *Seismic Hazard*
(Surface Rupture and Groundshaking)—Utilize Alquist-Priolo Special Fault Study Zone maps and studies, performed by the California Division of Mines and Geology, and results from USGS Professional Papers, to define local hazard zones.

Surface Rupture

Utilize the following methodology to evaluate the hazard of surface rupture: RESERVED FOR FUTURE DEVELOPMENT

Groundshaking

Utilize the following methodology to evaluate the hazard of groundshaking: RESERVED FOR FUTURE DEVELOPMENT

c. *Expansive Soils*

Utilize Soil Resource Inventories and published professional papers to define local hazards.

d. *Flood Hazard*

INTERIM STANDARD: Utilize Water Resource Inventories and field evidence to define flood hazard zones within 100 year recurrent event floodplain, or lakeplain. Based on local evidence, define the site as having the following hazards:

INTERPRETATION	CODE
No Hazard	(NULL)
Low Hazard	L
Moderate Hazard	M
High Hazard	H

Any landform lying within an area likely to be affected by a 100 year recurrent storm event should be considered to have a High Hazard. The Low and Moderate interpretations are to be used for areas where evidence is poor, but a flood hazard is suspected. The interpretation of No Hazard should be used for areas which you are certain are outside the potential flood zone. IN CONJUNCTION WITH OTHER AGENCIES, RESERVE FOR FUTURE DEVELOPMENT.

e. *GeoHazardous Materials*

Follow the Service-wide standard.

f. *Hazardous Workings*

Follow the Service-wide standard.

g. *Landslide Hazard*

INTERIM STANDARD: A Regional interim standard will be utilized, with the goal of adopting, modifying or developing a quantitative analytical method in the next several years. In the interim, perform a relative slope stability hazard analysis using the following concepts discussed by Varnes (1984).

Definition: Slope Stability Hazard—The division of the land surface into areas and the relative ranking of these areas according to degrees of actual or potential natural hazard from landslides or other mass movement on slopes. Natural hazard means the probability of occurrence within a specified period of time, and within a given area of a potentially damaging phenomenon.

Three principles need to be applied in order to evaluate slope stability hazards:

1) The past and present are keys to the future;
2) The main conditions that cause landsliding can be identified, and;
3) Degrees of hazards can be estimated.

The first principle means that natural slope failures in the future will most likely be in geologic, geomorphic and hydrologic situations that have led to past and present failures. Thus, we have the ability to estimate the style, frequency of occurrence, extent, and consequences of failures that may occur in the future. It does not necessarily follow that the absence of past or present failures means that failures will not occur in the future. In addition, new management activities may so alter the natural topographic and hydrologic conditions that the susceptibility for slope movement is greatly increased. This first principle is applicable only to the degree that the conditions of the past and present which led to failure can be identified, and that they either continue or that the effects of changed or new conditions can be evaluated.

The second principle which needs to be applied to slope stability hazard analysis is that the main conditions that cause landsliding can be identified. The basic causes of slope instability are fairly well known from a wealth of case studies of specific failures. Some are inherent in the rock or soil, in its composition or structure. Some, like inclination of undisturbed slopes, are relatively constant and some are variable, such as groundwater levels. Some are transient and some are imposed by new events such as construction activity. In a given area, most of these factors can be recognized and their effects rated or weighted: and some can be mapped and correlated with each other and with past failures. The aim should always be to develop an understanding of the processes involved; why landslides occur when and where they do and their mechanisms; for this permits prediction of susceptibility by extension of point or site information to larger areas.

The third principle is that degrees of hazard can be estimated. When the conditions and processes that promote instability can be identified, it is often possible to estimate their relative contribution and give them some qualitative or semi-quantitative measure, place by place. Thus, a summary of the degree of potential hazard in areas can be built up, depending on the number of failure inducing factors present, their severity and interaction.

This type of hazard analysis considers the relative hazard of the landform component, such as the valley inner gorge, toe zone of a translational slide, debris slide prone slope and crown scarp, in conjunction with material characteristics, slope steepness, local groundwater conditions, and other local factors including seismicity and climate.

The following relative or semi-quantitative hazard evaluation and codes will be used:

INTERPRETATION	ALPHA CODE	NUMERIC CODE
No Hazard	(NULL)	(NULL)
Low Hazard	L	1
	L	2
	L	3
Moderate Hazard	M	4
	M	5
	M	6
High Hazard	H	7
	H	8
	H	9
Extreme Hazard	E	10

Although there may be some reservations for using semi-quanitiative hazard ratings, when entered into a database, it will allow you to perform many types of analyses which will give you further insights into the relative hazards relating geomorphology to bedrock lithology, formation, soil type, slope steapness, etc.

h. *Subsidence*

Follow the Service-wide standard.

i. *Volcanic Hazards*

The source for this interpretation for all active or potentially active volcanoes in California will be Miller (1989). He defines two types of volcanic hazards: Flowage and Air Fall Tephra.

Flowage

Definition: Materials which are erupted into the air or onto the flanks of a volcano which move downslope under the influence of gravity. These materials move or flow away from a volcano either on its flanks or down valleys leading away from the volcano. such flowage phenomena may consist solely of lava or pyroclastic flows, or mixtures of lava blocks, lapilli and ash mixed with gases and/or water (mudflows).

There are three interpretations:

1) No Flowage Hazard.
Code: (NULL)

2) Flowage Hazard Zone for Locally Precedented Events—This includes areas most likely to be affected by future lava flows and domes, by pyroclastic flows and surges by lateral blasts, and at some volcanoes, debris flows and floods. These precedented events are based on the distribution of Holocene volcanic deposits.
Code: *PE*

3) Flowage Hazard Zone for Locally Unprecedented Events—This includes areas most likely to be affected by eruptions considerably larger than are precedented in the Holocene. The interpretation is based on the distribution of pre-Holocene deposits.
Code: *UE*

Air Fall Tephra

Definition: The likely distribution of rock and lava fragments, which are erupted into the air from volcanic vents, based on the volume of the eruption, the height of the eruption column, and the direction and speed of the prevailing wind.

There are three hazard zones for air fall tephra:

1) No Hazard—Based on precedented ashfalls, areas where there is no hazard.
Code: (NULL)

2) Large Precedented Hazard—Zones which represent an area where 20+ cm of compacted ash would be expected from future eruptions, which are similar to the largest ashfalls in the past 10,000 years.
Code: *PEX*

3) Moderate Precedented Hazard—Zones which represent areas where between 5 and 20 cm of ash would be expected from future eruptions.
Code: *PEY*

C. Geologic Stratigraphy

1. Service-Wide Standards

a. *Definition:*

The arrangement of rocks as classified by geographic position and chronologic order. The hierarchy of terms is province, terrain (where applicable), group (where applicable), formation, and member.

b. *Types:*

Physiographic Province—A region where all parts display similar geologic structure and climate and have a unified geomorphic history; differs significantly in patterns of relief features and landforms from adjacent regions.

Terrain—A fault-bounded body of rock of regional extent, characterized by a geologic history different from that of contiguous terranes; generally considered to be a discrete fragment of oceanic or continental material added by accretion.

Group—A unit consisting partly or entirely of named formations. Named for a geographic locality.

Formation—A mappable body of rock identified by distinctive characteristics, some degree of internal homogeneity, and stratigraphic position. The name normally consists of two parts. The first is the name of the geographic locality where the formation was first identified and described ("Type section"). This is followed by a descriptive geologic term, usually the dominant rock type. Most geologic mapping in support of forest planning is at the formation level.

Member—A specially developed unit, not necessarily mappable, of a formation. When named, it consists of a geographic name, an optional lithologic designation, and the word "member." In sedimentary formations, members may be locally subdivided into "beds."

c. *Measurements:*

Acres

d. *Examples:*

Coast Range Province
Sierra Nevada (province)
Rattlesnake Creek Terrain
San Rafael Group
Mancos Shale (formation)
Navajo Sandstone (formation)
Skyline Trail Conglomerate Member of the Hoback Formation

e. *Source for Data Standards:*

USGS Geologic maps and their related publications

2. Region 5 Data Standards

Physiographic Province—Follow the Service-wide standard.

Sub-Province or Complex—A geographic or stratigraphic subdivision of the geologic province or a large scale field association of different rocks of any age or origin, having common structural relationships.

Belt—A logical grouping of related geologic terranes, groups or formations.

Terrain—Follow the Service-wide standard, however, terrain can be used in the same manner that Formation is used.

Group—Follow the Service-wide standard.

Formation—Follow the Service-wide standard.

Member—Follow the Service-wide standard.

D. Geologic Structure

1. Service-Wide Data Standard

a. *Definition:*
The general disposition, attitude, arrangement, and relative position of the rock masses of an area.

b. *Types:*
Bedding—The general physical and structural character or pattern of the beds and their contacts within a rock mass. Usually only significant at large scales.

Contact—A plane or irregular surface between two types or ages of rocks, usually the boundary of two formations, members, or beds.

Fault—A fracture or zone of fractures along which there has been displacement of the sides relative to one another parallel to the fracture. Where vertical motion is involved, the "footwall" is the surface beneath the fracture. Faults may be classified based on the apparent movement of the blocks:

Normal Fault—The hanging wall appears to have moved downward relative to the footwall. Dips are usually in the 45-90° range. Also called "gravity fault."
Thrust Fault—The hanging wall appears to have moved upward relative to the footwall. Also called "reverse fault" if the dip is greater than 45° or "overthrust" if the dip is low angle and there is a great amount of displacement.
Strike-Slip Fault—A horizontal displacement parallel to the strike of the fault. Called "right-lateral" if the side opposite the observer appears displaced to the right, or "left-lateral" if displacement appears left.
Oblique Fault—Displacement is diagonal, or in an intermediate direction between horizontal and vertical.
Rotational Fault—Displacement increases outward from a point, so that alignment of formerly parallel features is disturbed. Also called a "hinge" fault.
Transform Fault—A special form of strike-slip fault, usually regional in scale, in which the displacement suddenly stops or changes form.

Fold Axis—The line of symmetry about which a previously planar structure, such as rock strata, bedding planes, foliation or cleavage, curves or bends. Folds may be classified based on the relationship of the limbs of the fold. Other descriptive terms used in describing folds are "asymmetrical" (strata of one limb dip more steeply than the other), "overturned" (limbs are tilted beyond the vertical and dip in the same direction, but not necessarily by the same amount), "recumbent" (one limb is inverted and the axis is nearly horizontal) and "isoclinal" (beds on both limbs nearly parallel).

<u>Anticline</u>—A generally convex upward fold, or arch, with the stratigraphically older rocks in the core.

<u>Syncline</u>—A generally concave upward fold, or trough, with the stratigraphically younger rocks in the core.

<u>Monocline</u>—A local steepening in an otherwise uniform gentle dip.

<u>Dome</u>—An uplift or anticlinal structure, either circular or elliptical in outline, in which the rocks dip gently away in all directions. (Also name of term in "Topographic Feature")

<u>Basin</u>—A low area or crustal downwarp in which the strata dip towards a common center, and in which sediments have accumulated. (Also name of term in "Topographic Feature")

<u>Foliation</u>—A general term for the planar arrangement of textural or structural features in any type of rock. Usually only significant at large scales.

<u>Joint</u>—A surface of fracture or parting in a rock, without displacement; the surface is usually plane and often occurs with parallel joints to form a joint set. "Sheeting" is a pattern of essentially horizontal joints. "Columnar" jointing results from contraction during the cooling of basalts and some other igneous rocks.

<u>Lineation</u>—A general, nongeneric term for any linear structure in a rock; eg. flow lines, slickensides, mineral streaking, and crinkles. Usually only significant at large scales.

c. *<u>Measurements:</u>*

The following attributes need to be tracked for this element:

##<u>Strike</u>—the direction or trend of a structural surface as it intersects the horizontal. The direction, or "bearing," of the line is expressed as the acute angle (##) with respect to the north/south line (**); for example, N60W.

##*<u>Dip</u>—the angle that a structural surface makes with the horizontal, measured perpendicular to the strike of the structure and in the vertical plane. Also called "plunge" when applied to the axis of a fold. Measurement is the vertical angle in degrees (##), followed by the primary direction (*) of dip; for example, 30N

d. *<u>Confidence Level:</u>*

The following terms relate to the confidence level of the presence of a structural feature:

<u>Known</u>—Location can be observed on the surface, measured, and mapped.
<u>Approximate</u>—Location is estimated between known points.
<u>Inferred</u>—Geologic evidence suggests the presence of a feature, but it has not been observed.
<u>Concealed</u>—Location is overlain by material, but there is direct evidence of presence (such as from drilling).

e. *Example:*
Fn/k/N80W/60N. A known normal fault which has a strike of north 80° west and dips 60° northerly.

f. *Source for Data Standards:*
Bates, R.L., and Jackson, 1987, Judson, S., M.E. Kauffman, and L.D. Leet, 1987, and Dietrich, R.V., J.T. Dutro and R.M. Foose, 1982.

2. Region 5 Data Standards

The Region will adopt the Service-wide Standard for the Geologic Structure Element.

E. Geologic Time Unit

1. Service-Wide Data Standards

a. *Definition:*
A division of time traditionally distinguished on the basis of observable changes in worldwide life forms as represented in the fossil record in sedimentary rocks. Radioactive dating of igneous and some sedimentary rocks is used to correlate absolute ages to the relative scale. This correlation is approximate and there are several estimates published in the literature. The ages below represent those used by the IUGS, the divisions by a working group from the USGS. (Units are million years before present—MYBP).

b. *Types and Codes:*

Symbol	Era	MYBP
Cz	Cenozoic Era—Age of recent life	
Q	—Quaternary Period—Development of human race	
	——Holocene (Recent) Epoch—(Last 10,000 years) ——Pleistocene Epoch—Ice age; mammoths; sabre-toothed tigers	
		2
T	—Tertiary (Neogene/Paleogene) Period—Development of mammals; western US lava flows; formation of the Basin and Range, Cascades, and Coast Ranges; culmination of Rocky Mountain uplift.	
Tpl	——Pliocene Epoch—	
		5
Tm	——Miocene Epoch—Abundant grasses; mammals dominant; Columbia River basalt flows	
		24
To	——Oligocene Epoch—Flowering plants dominant; central continent stable	
		37
Te	——Eocene Epoch—Formation of several ranges in Central Rockies (Laramide orogeny)	
		53
Tp	——Paleocene Epoch—First primates appear	
	The "K-T" boundary (period of mass extinction)	65

Symbol	Era	MYBP
Mz	<u>Mesozoic</u> Era—Age of dinosaurs	
K	—<u>Cretaceous</u> Period—North America separates from Eurasia; accretion begins along west coast; intercontinental seaway from Arctic to Gulf; western mountain building activity (Sevier orogeny)	
		135
J	—<u>Jurassic</u> Period—Birds first appear.	
		205
		205
T_R	—<u>Triassic</u> Period—Dinosaurs first appear; reptiles and conifers dominant. North America begins to separate from Africa as the Atlantic basin originates.	
		250
Pz	<u>Paleozoic</u> Era—Age of ancient life	
P	—<u>Permian</u> Period—Climax of Appalachian mountain building	
		290
Cp/P	—<u>Pennsylvanian</u> Period—Coal-forming swamps dominant; North America part of supercontinent "Pangaea"; warm, shallow seas.	
		~320
Cm/M	—<u>Mississippian</u> Period—First insect fossils and amphibians; ferns and coal-forming swamps abundant.	
(C)	—<u>Carboniferous</u> Period (combines Penn and Miss, used outside North America)	
		355
D	—<u>Devonian</u> Period—Life moves on land; first land plant fossils; fish abundant	
		410
S	—<u>Silurian</u> Period—Fish dominant; extensive coral reefs; "North America" collides with "Europe."	
		438
O	—<u>Ordovician</u> Period—Marine invertebrates dominant; trilobites abundant; vertebrates (fish) appear late in period; accretion of "North American" east coast and beginning of Appalachian Mountains.	
		510
-C-	—<u>Cambrian</u> Period—Marine invertebrates, plants, and algae dominant; supercontinent "Gondwanaland"; ancestral "North America" about half the present-day area, located along the equator	
		570
pC	<u>Precambrian</u>—generic term for undivided Proterozoic/ Archean time.	
Z	<u>Late Proterozoic</u> Eon—First multicelled organisms	
		1000
Y	<u>Middle Proterozoic</u> Eon—First complex-celled organisms	
		1600

Symbol	Era	MYBP
X	Early Proterozoic Eon—Early organic structures	
		2500
A	Archean Eon—Large cratons form; earliest life	
	Formation of Earth's crust	4550

c. *Measurements:*
million years before present (MYBP)

d. *Examples:*
See above

e. *Source for Data Standards:*
IUGS, 1989.

2. Region 5 Data Standards

Region 5 will adopt the Service-wide Geologic Age Data Standards.

F. Groundwater Geology

1. Service-Wide Data Standard

a. *Definition:*
The characteristics of subsurface water, with emphasis on the system that acts as the water-yielding hydraulic unit.

b. *Types:*
Aquifer—A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of ground water to wells and springs.

Confining Unit—A hydrogeologic unit of impermeable or distinctly less permeable material bounding one or more aquifers (general term replacing aquitard, aquifuge, and aquiclude).

Groundwater Basin—A groundwater flow system that has defined boundaries and may include permeable materials that are capable of storing or furnishing a significant water supply. Includes both the surface area and the permeable materials beneath it.

Recharge Area—That portion of a drainage basin in which water reaches the saturated zone through surface infiltration

Seep—An area, generally small, where ground water percolates slowly to the land surface.

Spring—A place where groundwater flows naturally onto the land surface, and may show thermal characteristics.

Water Table—The upper surface of a zone of saturation at which the water pressure in the porous medium is atmospheric. (Excludes surfaces formed by a confining unit)

Well—An artificial excavation sunk into the saturated zone to allow removal of the water or to allow monitoring groundwater quantity or quality.

c. *Measurements:*
Yields may be measured in gallons per minute (GPM)

d. *Example:*
See above

e. *Source for Data Standards:*
Bates, R.L, and Jackson, J.A., 1987, Freeze, R.A., and Cherry, J.A., 1979, EPA, 1989.

2. Region 5 Data Standard

Region 5 will adopt the Service-wide Groundwater Geology data standard.

G. Lithologic Unit

1. Service-Wide Data Standards

a. *Definition:*
A system of rock classification based on manner of origin, composition, and texture (or grain size). No one system is universally recognized; the following nomenclature is offered as a guide to common terms that would be significant in most Forest Service work.

b. *Types:*
(may be expanded regionally to provide for locally important subclasses).

Igneous—Rock that has solidified from molten or partly molten material (magma). The following igneous rock types are classified based on chemical content, generally progressing from light colored, silica-rich content to dark colored, ferromagnesian-rich (mafic) content.

Phaneritic Texture—Individual components can be identified with the unaided eye.
Syenite—Orthoclase (Potassium) feldspar greater than 2/3 total feldspar, quartz less than 10%
Granite—Orthoclase feldspar greater than 2/3 total feldspar, quartz greater than 10%
Monzonite—Orthoclase/Plagioclase ratio about equal, quartz less than 10%
Granodiorite—Plagioclase (Sodium/Calcium) feldspar greater than 2/3 total feldspar, quartz greater than 10%
Diorite—Plagioclase (Sodium-rich) feldspar, quartz less than 10%, mafic minerals about 25%
Gabbro—Plagioclase (Calcium-rich) feldspar about 50%, mafic minerals about 50%
Peridotite—Mafic minerals greater than 90%

Porphyritic Texture—Larger crystals set in a finer-grained groundmass. Takes name from dominant rock type (e.g., "granite porphyry.")

Pegmatitic Texture—Exceptionally coarsely crystalline, usually with a composition similar to granite. Commonly referred to as "pegmatite."

Aphanitic Texture—Individual components can not be identified with the unaided eye.
Trachyte—Extrusive equivalent of syenite
Rhyolite—Extrusive equivalent of granite
Latite—Extrusive equivalent of monzonite

Dacite—Extrusive equivalent of granodiorite
Andesite—Extrusive equivalent of diorite
Basalt—Extrusive equivalent of gabbro

Glassy Texture—Amorphous rock without distinct crystallization
Obsidian—Black to dark-colored volcanic glass, similar in composition to rhyolite.
Pumice—Light-colored, vesicular (filled with small cavities formed by entrapment of gases) glassy rock, similar in composition to rhyolite.
Tuff—A general term for all consolidated pyroclastic material, but typically refers to volcanic ash.

Sedimentary—Consolidated rock that has formed from the accumulation of materials on the Earth's surface. These are consolidated.
Gravel—Particle size greater than 2mm. [1]
Conglomerate—Consolidated gravel composed of rounded particles.
Breccia—Consolidated gravel composed of broken, angular particles.

Sand—Particle size between 1/16 and 2mm. [1]
Sandstone—Cemented sand. When used without a qualifier, generally contains about 90% quartz.
Arkose—Feldspar-rich (usually greater than 25%) sandstone that is not well-sorted.
Graywacke—A dark-gray, coarse-grained, poorly-sorted sandstone.

Mud—Particle size less than 1/16mm. [1] (Called "silt" when greater than 1/256mm, "clay" when less than 1/256mm)
Shale—Finely laminated, clayey rock with about 1/2 silt.
Siltstone—Similar to shale, but has greater than 2/3 silt and lacks the fine laminations.

Carbonate—A general rock type formed from organic and inorganic precipitation of calcium and magnesium carbonates.
Limestone—Contains more than 95% calcite (calcium carbonate)
Dolomite—Contains more than 90% of the mineral dolomite (calcium-magnesium carbonate)
Tufa—A spongy form of calcium carbonate created by evaporation around springs or from a lake surface.
Travertine—A dense, frequently concentric, form of calcium carbonate created by the rapid chemical precipitation from ground waters (limestone cave formations) or by evaporation around hot springs.

Silica—A general term for silicon dioxide
Chert—A dense, very hard rock composed of microcrystalline silica (varieties also called flint, jasper, agate)
Diatomite—A light-colored, soft rock composed of the siliceous skeletons of diatoms (water-dwelling organisms)

Phosphorite—Rock containing quantities of precipitated or reworked phosphate minerals.

[1] Note: size classification for gravel/sand/mud varies depending on use; the values shown above are as defined for geologic applications.

Hematite—A common iron oxide mineral, occurring in several forms, with a distinctive brick-red color when powdered.

Limonite—A general group of hydrous (contains water) ferric oxides, commonly having a dark brown or yellow-brown color.

Evaporite—A general group of rocks produced by the extensive evaporation of a saline solution.
Gypsum—A soft mineral consisting of hydrous calcium sulfate
Anhydrite—Anhydrous (does not contain water) calcium sulfate, similar to gypsum but harder and slightly less soluble.
Halite—Native salt

Carbonaceous—Rich in carbon or organic matter.
Peat—A soft, brown material containing the partially decomposed remains of plants.
Lignite—A soft, brown coal formed by the further compression of peat.
Coal, Bituminous—A harder, more compacted, black coal.
Coal, Anthracite—A very hard, black coal, actually classed as metamorphic.
Asphalt—A dark brown or black, low-melting point, bitumen (a natural inflammable substance) comprised almost entirely of carbon and hydrogen.

Metamorphic—Rock that has been derived from pre-existing rocks, essentially in the solid state, in response to changes in temperature, pressure, shearing stress, and chemical environment.

Foliate—A general term for planar or layered structure
Gneiss—A rock with alternating bands of granular and flaky (or elongate) minerals. Generally less than 1/2 the minerals show a preferred parallel orientation.
Schist—Can be readily split into thin flakes or slabs due to more than 1/2 the minerals showing a well-developed parallelism.
Phyllite—Contains platy minerals too small to be clearly identifiable, distinguished by a glossy sheen.
Slate—A very fine-grained rock, most often generated from the metamorphism of shale, exhibiting excellent cleavage.
Mylonite—A compact, chertlike rock without cleavage, but with a banded appearance produced by extreme shearing and pulverizing during metamorphism.

Massive—A general term denoting lack of foliation
Metaquartzite—Recrystallized sandstone or chert, consisting mainly of quartz.
Marble—Recrystallized calcite and/or dolomite, usually with a sugary texture.
Hornfels—A fine-grained rock with a mosaic of equidimensional grains.
Soapstone—A light-colored rock with a soft, soapy feel, having a fibrous or flaky texture, and composed chiefly of talc
Serpentine—A rock with a greasy or silky luster and a tough, conchoidal fracture, having a common greenish color and often veined or spotted.
Amphibolite—A dark-colored, medium-grained rock containing amphibole and plagioclase.

Migmatite—A composite rock containing both igneous and metamorphic materials

Unconsolidated—Sediment that has not been lithified. Describes the surficial layer below the soil horizons but above bedrock.
Alluvium—Deposited by running water (fluvial)
Colluvium—Deposited by rainwash, sheetwash, creep and/or mass wasting

Constructed—Landfills and earthworks
Eolian—Deposited by wind
Glacial—Deposited by action of glaciers or ice sheets
Lacustrine—Deposited on the bottom of a lake
Marine—Deposited on the bottom of a sea
Organic—Accumulations of organic matter
Transitional—Shoreline transition between marine and continental; includes estuarian environment.

c. *Measurements:*
Note: there are several properties of rocks that may be important to specific applications and interpretations. These may be defined and added locally. An example is the use of the Unified Rock Classification System (URCS) to further describe engineering-related properties.

d. *Example:*
N/A

e. *Source for Data Standards:*
Travis, R.B., 1955, Stanley, S.M., 1989, and Judson, et al, 1987.

2. Region 5 Data Standard

Region 5 will adopt the Service-wide data standard for Lithology, however, several additional lithologies have been added. Codes for lithology, which will be used for entry of data into the R5 EUI data base, are contained in **Appendix A**.

H. Topographic Feature (Geomorphology)

1. Service-Wide Data Standard

a. *Definition:*
Any physical feature of the earth's surface having a characteristic, recognizable shape and produced by natural causes. A topographic feature can be classified based on the process that created it and by its general shape (landform).

b. *Types:*

1) Geomorphic Process

Eolian—The erosion and deposition accomplished by the wind.

Fluvial—Produced by the action of a stream or river.

Glacial—Of or relating to the activities of past or present ice or glaciers.

Igneous—Landform produced by volcanic eruption, surface flows, or near-surface intrusions.

Karstification—The formation of features by the solutional, and sometimes mechanical, action of groundwater in a region of limestone, gypsum, or other soluble bedrock.

Lacustrine—Related to lake deposition or lake processes.

Mass Wasting—General term for the dislodgement and downslope transport of soil and rock material under the direct influence of gravity.

Shoreline—Pertaining to the interface between the marine and continental environment.

Surface erosion—The mechanical destruction and removal of materials by running water.

Tectonic—Folded and fault-controlled structures produced by movements of the earth's crust.

2) Landshape

Backslope—The component of the hillslope that forms the steepest inclined surface and is frequently the principal element. The surface is dominantly steep and linear in profile and erosional in origin.

Badlands—Intricately stream-dissected topography characterized by a very fine drainage network with high drainage densities and short, steep slopes. They have little or no vegetative cover overlying consolidated or poorly cemented clays or silts.

Bajada—A broad, gently inclined slope formed by the lateral coalescence of a series of alluvial fans, and having a broadly undulating transverse profile.

Basin—A depressed area with no surface outlet.

Bench—A long, narrow, relatively level or gently inclined strip or platform of land, earth, or rock, bounded by steeper slopes above and below.

Butte—An isolated, usually flat-topped upland mass characterized by summit widths that are less than heights of the bounding erosional escarpment. It is produced by differential erosion of nearly horizontal, interbedded weak and resistant rocks. See also mesa.

Caldera—A large, basin-shaped volcanic depression, more or less circular in form, and having a diameter many times greater than the included volcanic vents. See also crater.

Canyon—A long, deep, narrow, very steep-sided valley with high and precipitous walls in an area of high local relief.

Cirque—Semicircular, concave, bowl-like area with steep face primarily resulting from erosive activity at the head of a mountain glacier.

Cliff—A high, very steep to perpendicular or overhanging face of rock or earth.

Cone—A conical hill of lava or cinders that is built up around a volcanic vent.

Crater—A basinlike rimmed structure, usually at the summit of a cone; its floor is approximately the diameter of the vent. See also caldera.

Divide—The line of separation marking the boundary between two adjacent drainage systems.

Dome—A smoothly rounded landform or rockmass, such as a rock-capped mountain summit.

Draw—A small stream channel, generally more open and with a broader floor than a gulch. Also locally called "arroyo" or "wash."

Dune—A mound, ridge, or hill of loose, windblown granular material (generally sand), either bare or covered with vegetation.

End Moraine—The moraine produced at the front of an actively flowing glacier at any given time.

Escarpment—A relatively continuous and steep slope or cliff breaking the general continuity of more gently sloping land surfaces and produced by erosion or faulting. When applied to cliffs formed by faulting, commonly abbreviated to "scarp."

Fan—A gently sloping, fan-shaped mass of detritus forming a section of a very low cone commonly at a place where there is a notable decrease in gradient.

Flat—A level or nearly level area of land marked by little or no relief.

Floodplain—The nearly level alluvial plain that borders a stream and is subject to inundation under flood stage conditions.

Foot Slope—The component of the hill slope that forms the inner, gently inclined surface at the base. The surface is dominantly concave in profile and is transitional between erosion and deposition.

Gorge—A narrow, deep valley with nearly vertical rocky walls; used especially to identify a restricted, steep-walled part of a canyon.

Ground Moraine—An extensive, fairly even and undulating layer of rock debris which has been primarily deposited from underneath the glacier.

Gulch—A small stream channel, narrow and steepsided in cross section. Also called "ravine."

Hill—A natural elevation of the land surface, rising as much as 1000 ft (see mountain) above the surrounding lowlands, usually of restricted summit area and having a well-defined outline. Hills fringing a mountain range are called "foothills."

Hillslope—The steeper part of a hill between its summit and the drainage line or valley floor. Components of the hill slope may be further classified as shoulder, backslope, footslope, and toe slope.

Hogback—A sharp-crested, symmetric ridge formed by the differential erosion of highly tilted and resistant rock layers.

Knob—A small, rounded hill, commonly isolated or rising above adjacent landforms. Also called "knoll."

Lateral Moraine—A ridge-like moraine carried on and deposited at the side margin of a valley glacier.

Mesa—A broad, nearly flat-topped, and usually isolated upland mass characterized by summit widths that are greater than the heights of bounding escarpments. As summit area decreases relative to height, mesas are transitional to buttes.

Moraine—An accumulation of rock material, with an initial topographic expression of its own, built chiefly by the direct action of glacial ice or by running water emanating from the glacier. Moraines may be classified as end moraine, ground moraine, lateral moraine, recessional moraine, or terminal moraine depending on their relationship to the movement of the ice mass.

Mountain—A natural elevation of the land surface, rising more than 1000 ft (see hill) above the surrounding lowlands, usually of restricted summit area (see plateau), and generally having steep sides.

Peak—Sharp or rugged upward extension of a ridge chain, usually at the junction of two or more ridges; the prominent highest point of a summit area.

Piedmont—An area or feature at the base of a mountain or mountain range.

Pinnacle—A tall slender tapering tower or spire-shaped pillar of rock, either isolated or at the summit of a mountain or hill.

Plain—An extensive lowland area that ranges from level to gently sloping or undulating.

Plateau—An extensive upland mass with a relatively flat summit area that is considerably elevated above adjacent lowlands, and is separated from them on one or more sides by escarpments. A comparatively large part of its total surface is at or near the summit level. See mesa and mountain.

Playa—The usually dry and nearly level lake plain that occupies the lowest parts of a closed basin.

Recessional Moraine—An end moraine, built during a temporary but significant halt in the final retreat of a glacier.

Ridge—A long, narrow elevation of the land surface, usually sharp crested with steep sides and forming an extended upland between valleys.

Saddle—A low point on a ridge or crestline, generally a divide between the heads of streams flowing in opposite directions.

Shoulder—The component of the hill slope that forms the uppermost inclined surface. The surface is dominantly convex in profile and erosional in origin.

Sinkhole—Circular depression in a karst area which is funnel-shaped, drainage is subterranean, and its size is measured in meters or tens of meters.

Stream Terrace—One of a series of platforms in a stream valley, flanking and generally parallel to the stream channel, originally formed near the level of the stream, and representing the dissected remnants of an abandoned flood plain produced during a former stage of erosion or deposition.

Structural Bench—A platform-type, nearly level to gently inclined erosional surface developed on resistant strata in areas where valleys are cut in alternating strong and weak layers with an essentially horizontal attitude.

Summit—A general term for the top, or highest level, of the relatively undissected upland between two adjacent valleys.

Table Mountain—A mountain having a comparatively flat summit and one or more precipitous sides.

Terminal Moraine—An end moraine that marks the farthest advance of a glacier and usually has the form of a massive arcuate ridge, or complex of ridges.

Terrace—Any long, narrow, relatively level or gently inclined surface, generally less broad than a plain.

Toe Slope—The component of the hill slope that forms the outermost, gently inclined surface at the base. The surface is dominantly linear in profile and depositional in origin.

Valley—An elongate, relatively large, externally drained, gently sloping depression of the Earth's surface commonly situated between two mountains or ranges of hills or mountains. It is usually developed by stream erosion.

Valley Floor—The gently sloping to nearly level bottom surface of a valley

c. *Measurements:*

The following attributes may need to be tracked for this element:

Elevation—Vertical distance from a datum, usually Mean Sea Level, to a point or object on the earth's surface. (Note: the term "altitude" is generally used to refer to points above the earth's surface). Measurements are generally expressed in feet, but metric system may be used if clearly identified. Accuracy will vary depending on source of data; standard USGS topo map data is at a vertical accuracy of +/- one-half the contour interval.

Slope—The ratio of vertical rise to horizontal distance, expressed as a percent (where horizontal=0% and 45°=100%), and measured in the direction of steepest gradient (perpendicular to the contour lines). For other than a few site-specific applications, slopes are generated from a terrain model and represent an average over an area. Accuracy depends on several factors: accuracy of elevation data, method of collection, and method of computation; common usage would suggest rounding to nearest 5%. Planning applications at 1:12,000-1:24,000 scale are frequently "isoslope" maps, with zones shown based on a limited number of user-defined slope ranges (e.g., 0-10%, 10-35%, 35-70%, 70%+)

Aspect—The direction toward which a slope faces with respect to the compass, measured in degrees clockwise from true north (azimuth). As with slopes, aspects are usually generated from a terrain model, and the same accuracy limitations apply. Most planning applications at 1:12,000-1:24,000 scales break aspects into quadrants or octants ("isoaspect" zones). A commonly used method is to center the arcs on the cardinal directions; e.g., "north facing" aspect in an octant system would be from azimuth 337° (NNW) to azimuth 22° (NNE). In practice, level or nearly level slopes are not considered to have a meaningful aspect. There are no standards defining this breakpoint, but a working assumption would be a value less than 5%.

d. *Example:*
See above

e. *Source for Data Standards:*
American Congress of Surveying and Mapping and the American Society of Civil Engineers, 1978, Bloom, A.L., 1978, Ritter, D.F., 1987 and National Soils Handbook, 1985.

2. Region 5 Data Standards

The Geomorphology Element of the Geology Data Standards is subdivided into two distinct areas; process and landshape. Geomorphic process is a combination of the primary geologic process which shaped the landform, and a traditional landform term. For example, in mapping and describing a mass wasting feature, it may be defined at a broad scale as a slide, at a more refined level a translational slide, and at a very detailed level as the toe, bench and crown-scarp landforms of a translational slide. Therefore, both process and landform terms are used.

In contrast, the landshape element is a combination of both traditional landform terms and descriptive landshape terms. These terms have traditionally been used by the Soil Conservation Service. Many of the landshape terms do not have any geomorphic conotations, or may contain a vast combination of processes. For instance, the landshape terms "canyon, hill, knob, flat, and ridge" are descriptive in nature, and may be formed and influenced by a wide variety of geomorphic processes.

Many of the landshape terms may be useful in broad inventories, such as Order 4 EUI, where mapping units are very large. However, these terms have a limited use in more detailed Order 2 and Order 3 EUIs. In general, Landshape is considered to be a generic description of the land surface in contrast to geomorphic process, which better specifies the landform and process responsible for shaping it.

The following section will present standard classifications, terms and definitions used in the Region 5 Geomorphic Process portion of the Geomorphic Element for Region 5 CRIs. The Region 5 landshape portion of the element is presently under development, in conjunction with the Soil Resource Group.

On the next page is a list of the Service-wide Geomorphic data elements, which were discussed in the preceding section, and their status as Regional data standards. If reserved, no additional Regional standard is presently proposed and the Service-wide standard will be utilized. The standard is meant only as a minimum standard; further subdivision may locally be warranted.

PROCESS	STATUS
Eolian	Reserved
Fluvial	Regional Standard
Mass Wasting	Regional Standard
Glacial	Regional Standard
Shoreline	Reserved
Igneous	Regional Standard
Karstification	Reserved
Tectonic	Regional Standard
Periglacial	Reserved
Lacustrine	Regional Standard

The following will present the Regional Data Standards and definitions for the Geomorphic Process data elements referred to above.

a. *Eolian*
This element is presently reserved, therefore, the Service-wide standard will be utilized.

b. *Fluvial*

Types:

1) Eroding Hillslopes—The steeper part of a hill between its summit and the valley floor where sheet and rill erosion are the dominant erosional processes.

2) Undifferentiated Stream System—Stream systems which are not differentiated as entrenched, meander or braided. Components can include:
Stream Channel—The bottom and lateral margins of a water course where a natural stream of water runs.
Floodplain—A nearly level alluvial plain that borders a stream and is subject to inundation under flood stage conditions.

3) Entrenched Stream System—This type of stream system has a floodprone width/ bankfull width ratio of less than 2.2. It is often bedrock controlled, however can also be incised into older fluvial deposits. Generally, it consists of Rosgen (1989) Stream Channel Types A, B, F and G. These systems can be relict from the Pleistocene, which do not flow water, or active (Recent), which annually do flow water. Components can include:
Stream Channel—The bottom and lateral margins of a water course where a natural stream of water runs.
Floodplain—A nearly level alluvial plain that borders a stream and is subject to inundation under flood stage conditions.

4) Meander Stream System—This mature stream system generally has attained a profile of equilibruim and a velocity that is just sufficient to carry the sediment delivered by its tributaries. This type of stream system has a floodprone width/ bankfull width ratio of greater than 2.2 and generally is very sinuous. Generally, it consists of Rosgen (1989) Stream Channel Types C and E. These systems can be relict

from the Pleistocene, and do not flow water, or active (Recent), which annually do flow water. Components can include:

Stream Channel—The bottom and lateral margins of a water course where a natural stream of water runs.

Floodplain—A nearly level alluvial plain that borders a stream and is subject to inundation under flood stage conditions.

5) Braided Stream System—A stream system that divides itself or follows an interlacing or tangled network of several small branching and reuniting shallow channels, resembling in plan the strands of a complex braid. Such a stream is generally believed to indicate an inability to carry all its sediment load. This type of stream system has a floodprone width/bankfull width ratio of greater than 2.2. Generally, it consists of Rosgen (1989) Stream Channel Type D. These systems can be relict from the Pleistocene, and do not flow water, or active (Recent), which annually do flow water. Components can include:

Stream Channel—The bottom and lateral margins of a water course where a natural stream of water runs.

Floodplain—A nearly level alluvial plain that borders a stream and is subject to inundation under flood stage conditions.

6) Stream Terrace—One of a series of platforms in a stream valley, flanking and generally parallel to the stream channel, originally formed near the level of the stream, and representing the dissected remnants of an abandoned floodplain produced during a former stage of erosion or deposition. Composed of a tread, which is the flat surface representing the level of the former floodplain, while the scarp is the steep slope connecting the tread to any surface standing lower in the valley.

Depositional Terrace—The tread represents the uneroded surface of a valley fill.

Erosional Terrace—The tread has been formed primarily by lateral erosion. If the lateral planation truncates bedrock, the term strath is commonly used, while if the erosion crosses unconsolidated debris, the term fillstrath is used.

7) Alluvial Fans - A gently sloping, fan-shaped mass of detritus forming a section of a very low cone, deposited by a stream, commonly at a place where it issues from a narrow mountain valley upon a plain or broad valley or where there is a notable decrease in gradient. Formed through a combination of viscous and non-viscous flow processes.

Proximal Facies—The uppermost portion of the alluvial fan as it emerges from the narrow mountain valley, characterized by coarse clastic material, and an active stream channel.

Medial Facies—The middle portion of a fan surface containing less course material, relative to the proximal facies, and many stream channels.

Distal Facies—The lower, gently sloping facies of an alluvial fan characterized by fine-grained material and low slope gradients.

8) Bajada—A broad gently inclined slope formed by the lateral coalescence of a series of alluvial fans and having a broadly undulating transverse profile.

Fan Skirt—The lower, low gradient slopes of a bajada.

9) Pediment—A broad sloping rock-floored erosion surface or plain of low relief developed by fluvial processes, at the base of an abrupt and receding mountain front or plateau.

10) Bolson—A term applied to an extensive flat alluvial floored basin or depression, into which drainage from the surrounding mountains flows centripetally, with gentle gradients toward a playa or central depression.

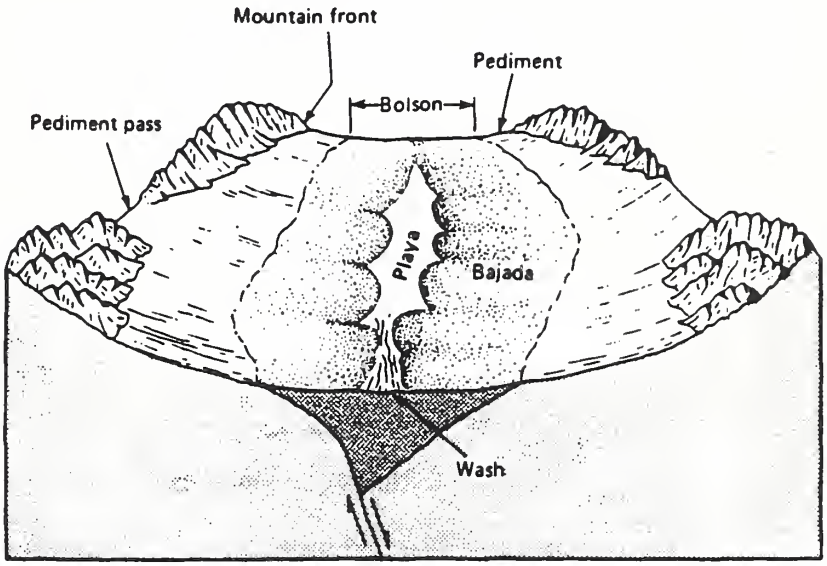

Figure 1 — Assemblage of fluvial/lacustrine features in mountainous desert environment. (Bloom, 1991)

Source for Data Standards:

Ritter, D.F., 1986, Bloom, A.L., 1978, Bates, R.L., and Jackson, J.A., 1987, and Rosgen, D., 1989.

c. *Mass Wasting*

1) Falls—A mass of any size is detached from a steep slope or cliff, along a surface on which little or no shear displacement takes place, and descends mostly through the air by free fall, leaping, bounding, or rolling; movements are very rapid to extremely rapid. Subdivisions include rock falls, debris falls and soil falls. Process includes source zones, transport zones and deposits (talus).

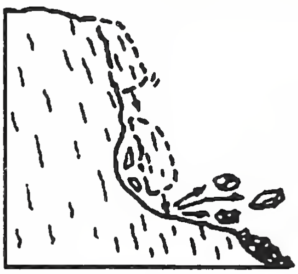

Figure 2 — Rock fall (Varnes, 1978)

2) Topples—Movement due to the forward rotation of a unit or units about some pivot point, below or low in the unit, under the action of gravity and forces exerted by adjacent units or by fluid in cracks; if unchecked, may result in a fall or slide. Subdivisions include source and deposits (talus).

3) Slides—Movement of material involving shear strain and displacement along one or several surfaces that are visible or may reasonably be inferred, or within a relatively narrow zone; movement may be progressive in nature.

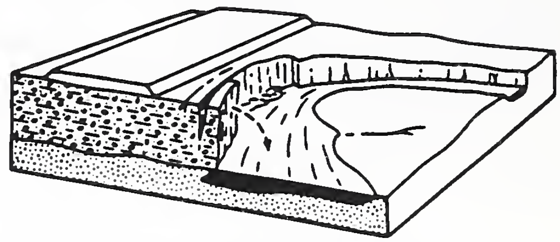

Figure 3 — Topple, debris (Varnes, 1978)

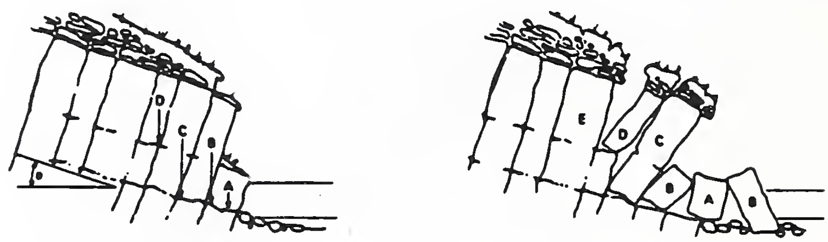

Figure 4 — Sequence of Topple, rock (Varnes, 1978)

Rotational (slump)—Movement due to forces that cause a turning movement about a point above the center of gravity of the unit; surface of rupture concaves upward and, along with the exposed scarp, is spoon-shaped. Movement ranges from extremely slow to rapid, depending on the material. Subdivisions include rock slumps, debris slumps and earth slumps.

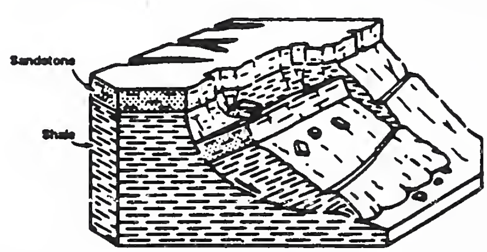

Figure 5 — Slide, Rotational rock slump (Varnes, 1978)

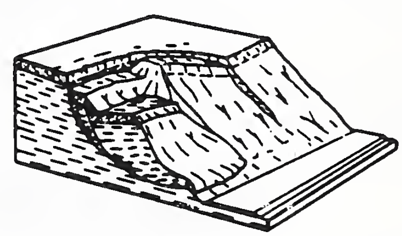

Figure 6 — Slide, Rotational earth slump (Varnes, 1978)

Translational Block Slide—Movement of mass predominantly along more or less planar or gently undulatory surfaces; movement frequently structurally controlled by surfaces of weakness or by the contact between firm bedrock and overlying detritus. Process and landform subdivisions include main scarp, further subdivided into debris slide-prone and nested main scarp, secondary scarp, bench, further subdivided into eroded and nested bench, and toe zone, which is further subdivided into nested toe. Block glides have generally moderately to deep-seated failure planes.

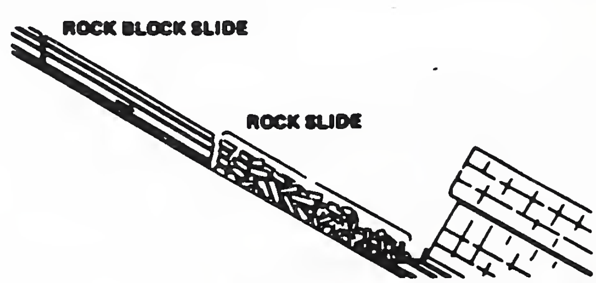

Figure 7 — Slide, translational, rock block and rock slides (Varnes, 1978)

Translational Debris Slides—Movement of mass predominantly along more or less planar or gently undulatory surfaces; movement frequently structurally controlled by surfaces of weakness or by the contact between firm bedrock and overlying detritus. Process and landform subdivisions include main scarp, further subdivided into debris slide-prone and nested main scarp, secondary scarp, bench, further subdivided into eroded and nested bench, and toe zone, which is further subdivided into nested toe. Debris slides have generally shallow to moderately seated failure plance.

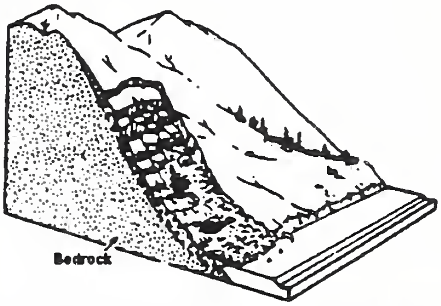

Figure 8 — Slide, translational, debris slide (Varnes, 1978)

Translational-Rotational Slides—Movement of a mass of material along a failure plane which varies from planar to curving. Movement can range from gradual to rapid depending on material and other local conditions. Subdivisions include rock translational-rotational slides, Debris Translational-Rotational slides and earth translational-rotational slides. Process and landform subdivisions include main scarp, further subdivided into debris slide-prone and nested main scarp, secondary scarp, bench, further subdivided into eroded and nested bench, and toe zone, which is further subdivided into nested toe.

4) Lateral Spreads—Distributed lateral extension movements in a fractured mass, a) without a well-defined controlling basal shear surface or zone of plastic flow (predominantly in bedrock) or, b) in which extension of a rock or soil results from liquefaction or plastic flow of subjacent material.

Rock Spread—Distributed lateral extension movement in a predominantly fractured bedrock mass without a well defined controlling basal shear surface or zone of plastic flow; movement usually extremely slow.

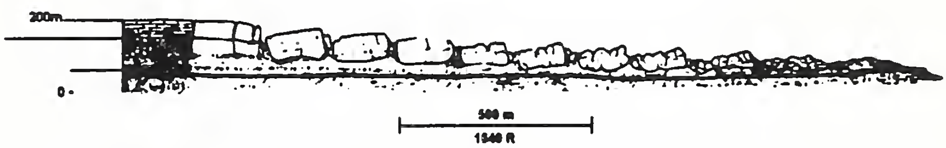

Figure 9 — Lateral spread, bedrock (Varnes, 1978)

Earth Lateral Spread—Distributed lateral extension movements involving fine-grained material which involves extension of material as a result of liquefaction or plastic flow of subjacent material; movement is very rapid.

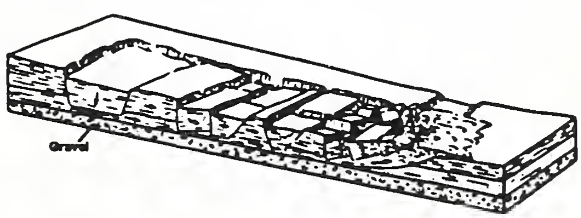

Figure 10 — Lateral spread, earth lateral spread (Varnes, 1978)

5) <u>Flow</u>—Movement of a slope which cannot be classified as falls, topples, slides or spreads; movement is fluid-like and can occur in wet or dry material where movement varies from slow to rapid.

In Bedrock—Includes spatially continuous deformation and surficial as well as deep creep (deformation that continues under constant stress) and involves extremely slow and generally nonaccelerating differential movements among relatively intact units.

In Soil—Movement within displaced mass such that the form taken by the moving material or the apparent distribution of velocities and displacements resemble those of viscous fluids.

<u>Debris Flow</u>—Very rapid flow movement of material which contains a relatively high percentage of coarse fragments and commonly results from unusually heavy precipitation or from thaw of snow or frozen soil. Process involves a source zone, transport zone and deposit zone.

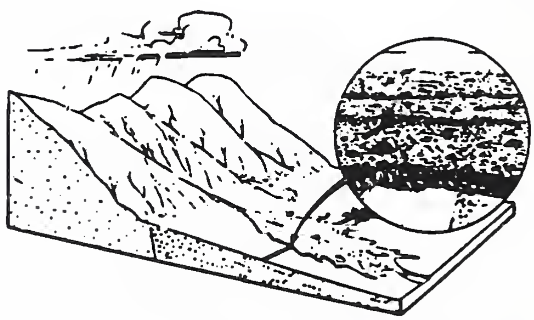

Figure 11 — Flow, debris flow (Varnes, 1978)

<u>Debris Avalanche</u>—Very rapid to extremely rapid movement of material which contains a relatively high percentage of coarse fragments. Process involves a source zone, transport zone and deposit zone.

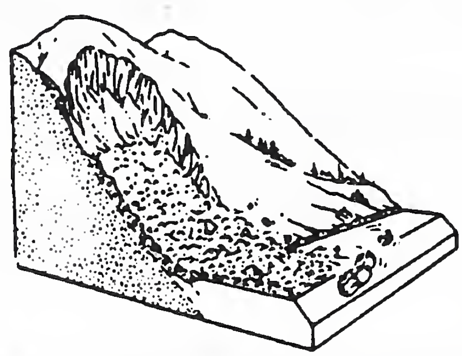

Figure 12 — Flow, debris avalanche (Varnes, 1978)

<u>Debris Torrent</u>—A rapid movement of water-charged soil rock and organic material down high gradient stream channels. They are generally initiated during extreme discharge events by a streamside debris avalanche which enters a flowing channel and entrains organic debris and sediment through scouring as it moves downchannel. When momentum is lost, or a significant obstruction is encountered, flow material is deposited.
<u>Block Stream Flow</u>—Extremely slow movement of tongues of rocky debris on steep slopes often fed by talus cones at the head.
<u>Solifluction</u>—Flowing movement of surficial debris mainly soil; in areas of perennially or permanently frozen ground often called gelifluction.

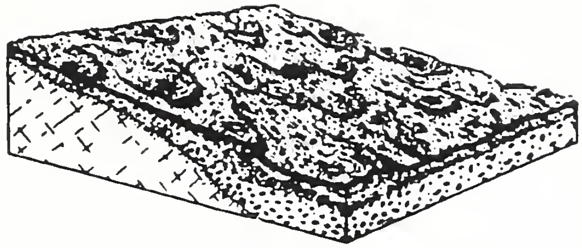

Figure 13 — Flow, solifluction (Varnes, 1978)

Soil Creep—Extremely slow, down slope movement of soil; deformation of the soil is continuously under constant stress. Landform can be described as a colluvial hillslope, colluvial ridgetop or colluvial apron.

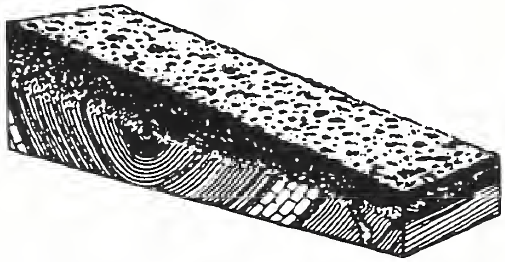

Figure 14 — Flow, soil creep (Varnes, 1978)

Earth Flow—Subaerial flows in fine-grained material such as sand, silt, or clay which vary in form and range in water content from above saturation to essentially dry and in velocity from extremely rapid to extremely slow. Process generally involves a main scarp, secondary scarp, bench and toe zones.

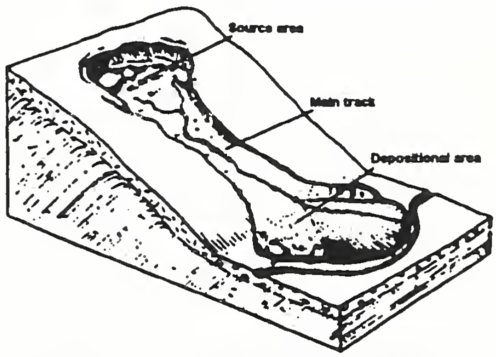

Figure 15 — Flow, earthflow (Varnes, 1978)

Dry Flow—Flow originating in fine-grained material which is essentially dry.
Dry Sand Flow (ravel)—Rapid to very rapid flow movement in sand sized material. Landform is a ravel cone or ravel apron.

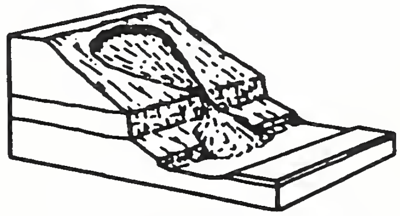

Figure 16 — Flow, dry sand flow (Varnes, 1978)

Loess Flow—Extremely rapid movement of dry material caused by earthquake shock.

6) Complex—Movement is by a combination of one or more of the five major types of movement listed above; though complex, many landslides will exhibit one type of movement as being the predominent movement.

Rock Fall-Debris Flow (Rock-Fall Avalanche)—Extremely rapid rock-fragment flow. Process involves source, transit and deposit zones.

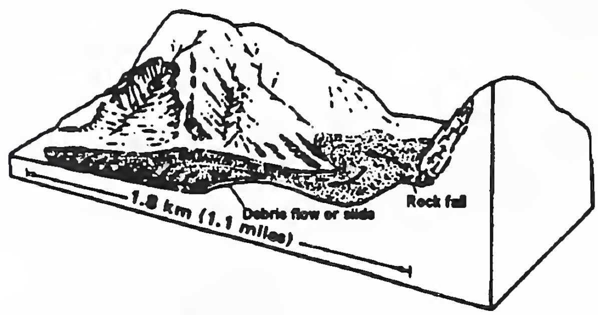

Figure 17 — Complex, rock fall—debris flow (Varnes, 1978)

Slump and Topple—Process involves source, transit and deposit zones.

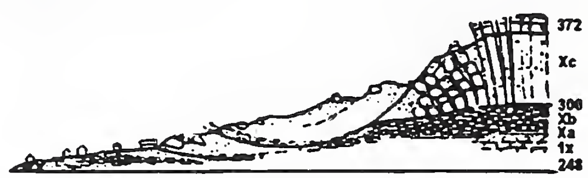

Figure 18 — Complex, slump and topple (Varnes, 1978)

Rock Slide-Rock Fall—Process involves source, transit and deposit zones.

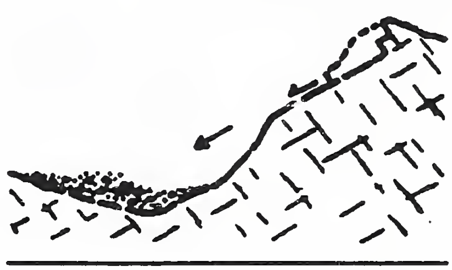

Figure 19 — Complex, rock slide—rock fall (Varnes, 1978)

Slump-Earth Flow—Process and landforms are greatly subdivided, due to the common and complex nature of this mass wasting type. Components include toe zone; subdivided into nested toe zone, primary scarp; subdivided into nested and DS prone, secordary scarp; further subdivided into nested, lateral; subdivided into nested and DS prone, bench; subdivided into nested bench, floating block and sag pond.

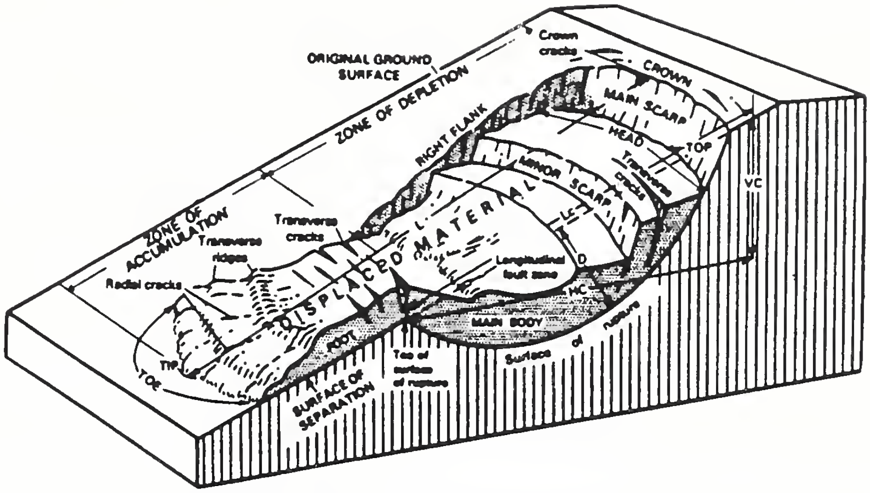

Figure 20 — Complex, slump earthflow (Varnes, 1978)

Internested Translational-Rotational Slides—Process involves multiple crown, bench and toe zones.

Debris Slide Basin—A basin ranging in size from several tens of acres to several hundred acres which appears to have fomed through a series of independent debris slide events. The sideslopes are generally steep and dissected.

Valley Inner Gorge. Those lowermost slopes adjacent to stream channels having gradients in excess of 65 percent, which are separated from the upslope area by a distinct break in slope. The valley inner gorge is formed primarily through mass wasting triggered by channel downcutting, oversteepening and undercutting. Different types can be defined on the basis of material and process, such as relict, primary and secondary.

Source for Data Standards:

Modified Varnes, 1978.

d. *Glacial Geomorphology*

1) Erosional:

Arete—A sharp-crested narrow, knife-like ridge separating two adjacent glaciated valleys.

Cirque—A semicircular concave, bowl or amphitheater-like hollow usually possessing three distinctive elements: a steep, nearly vertical headwall, a concave floor meeting the headwall in a sharp break in slope and a lip or threshold at the entrance which may be of bedrock, glacial moraine or both, resulting from erosional activity by a mountain glacier.

Horn—A high pyramid-like peak with steep sides, formed by the intersecting walls of several cirques surrounding a mountain summit.

Tarn—A small mountain lake that occupies the basin of a cirque.

2) Depositional:

Drumlin—A streamline asymmetrical oval-shaped hill composed of glacial drift (till), with its long axis parallel to the direction of flow of a former glacier where the steep side of the hill faces the direction from which the ice advanced.

Esker—A sinuous ridge composed largely of sand and gravel, deposited by a meltwater stream flowing in a tunnel beneath a glacier near its terminus.

Kame—A low, steep-sided hill of stratified drift composed of sand and gravel which is the result of original deposition modified by settling during the melting of glacial ice against or upon which sediment is collected.
Kame Terrace—A narrow, terrace-like mass of stratified glacial sand and gravel deposited between a glacier and adjacent valley wall.
Moraine—An accumulation of glacial drift having initial constructional topography built by the direct action of glacial ice, or by running water emanating from the glacier.

End Moraine—A ridgelike accumulation of glacial drift at the front of an actively flowing glacier.
Ground Moraine—An extensive, fairly even and undulating layer of glacial drift (till) deposited as a veneer of low relief over preexisting topography.
Lateral Moraine—An elongate ridge of glacial drift (till) deposited along the sides of an alpine glacier composed primarily of debris that fell to the glacier from the valley walls.
Medial Moraine—An elongate body of glacial drift (till) on a glacier formed by the joining of adjacent lateral moraines below the junction of two valley glaciers.
Recessional Moraine—An end or lateral moraine built during a temporary but significant pause in the final retreat of a glacier.
Terminal Moraine—A ridge of glacial drift (till) marking the farthest advance of the glacier.

Rock Glacier—A mass of poorly sorted angular boulders and fine material, with interstitial ice a meter or so below the surface or containing a buried ice glacier.
Outwash Plain—A relatively flat, gently sloping plain consisting of stratified drift deposited by meltwater streams beyond the margin of a glacier or ice sheet.
Valley Train—A long narrow body of outwash, deposited by meltwater streams far beyond the terminal moraine or the margin of an active glacier and confined within the walls of a valley below the glacier.
Outwash Terrace—A dissected and incised valley train or benchlike deposit extending along a valley downstream from an outwash plain or terminal moraine.

Source for Data Standards:
Ritter, D.F., 1986, Bloom, A.L., 1978 and Bates, R.L., and Jackson, J.A., 1987.

e. *Shoreline*
This element is reserved for defining in the future.

f. *Igneous*

1. Extrusive (Volcanic)

Volcano—A vent in the surface of the earth through which magma and associated gases and ash erupts

Shield—A broad, gently sloping volcano built from fluid basaltic or rhyolite lavas.
Composite—A volcano composed of inter-layered lava flows and fragmental material having slopes intermediate between cinder cones and shield volcanoes.
Cinder Cone—A conical hill formed by the accumulation of cinders and other pyroclasts, generally of basaltic or andesitic composition.
Spatter Cone—A low, steep-sided cone built of very fluid pyroclasts built up on a fissure or vent.

Lava Cone—A steep-sided cone built nearly or entirely by viscous to semi-viscous lava flows.

Domes—A smoothly rounded landform, formed through volcanic processes
Lava Dome—A bulbous mass produced when thick lava is slowly squeezed from the vent but does not travel far from the vent.
Plug Dome—A volcanic dome characterized by an upheaved, consolidated conduit filling.

Lava Flow—A lateral, surficial outpouring of molten lava from a vent or fissure.
AA Flow—A type of lava flow typified by a rough, jagged, spinous, clinkery surface.
Pahoehoe Flow—A type of fluid lava flow exhibiting a wrinkled, twisted ropy or tapestry-like surface, often distinguished by a smooth glistening skin.
Block Flow—A type of viscous lava flow where the front of the flow solidifies and the individual blocks of lava tumble over the edge and are overridden as the flow advances; the flow is characterized by a very rough, blocky appearance.
Older Flow—A lava flow which is of sufficient age where it is difficult to distinguish the type of flow that it originated as.

All of these flow types can be further subdivided on the basis of internal relief, ie. low relief; <6 feet, moderate relief; >6 feet < 20 feet, and high relief: > 20 feet.

Pyroclastic Flow—A density current, generally a highly heated mixture of volcanic gases and pyroclastic material, travelling down the flanks of a volcano or along the surface of the ground. the surface of the flow can vary from relatively smooth, to very blocky, depending on the composition and size of the pyroclasts.

Lahar—A mudflow composed chiefly of volcaniclastic materials on the flank of a volcano.

Caldera—A large basin-shaped volcanic depression, more or less circular in form, and having a diameter many times greater than the included volcanic vents.

Crater—A basin-like, rimmed structure that is usually at the summit of a volcanic cone.

Lava Tubes (collapsed)—Tunnels formed when the molten interior of a flow breaks out and leaves the earlier solidified sides and tops; when collapsed, the tunnels leave elongate depressions on the surface of the flow.

Tephra Fields—A well defined area which is covered by tephra, which was ejected from a volcano and transported through the air. It includes volcanic dust, ash, cinders, lapilli, scoria, pumice, bombs and blocks.

2. Intrusive

This element is reserved for defining in the future.

Source for Data Standards:

Ritter, D.F., 1986, Bloom, A.L., 1978 and Bates, R.L., and Jackson, J.A., 1987.

g. *Karstification*

This data standard is reserved for defining in the future.

h. *Lacustine*

All lakes may have the following features:

Lake Plain (Playa)—The nearly level surface marking the floor of an extinct lake, filled in by well-sorted deposits from inflowing streams; a flat lowland or a former lake bed bordering an existing lake.
Lake Terrace—A narrow shelf, partly cut and partly built, produced along a lake shore in front of a nip or line of low cliffs, and later exposed when the water level falls. Abandoned shorelines may be displayed on the lake terrace.

1) Tectonic—Lakes caused by crustal movement, including uplift, folding and faulting.

2) Volcanic—Lakes associated with volcanic activity, including lakes in crators, calderas, modified calderas, collapsed lava flows and lakes formed by barrier lavas.

3) Landslide—Lakes resulting from landslides damming stream channels.

4) Glacial—Lakes formed by glacial agents, including ice lakes, rock basin lakes, moraine lakes, kettle lakes, and pingo lakes.

5) Solution—Lakes resulting from the solution of limestone.

6) Fluviatile—Lakes formed by fluvial action including Pleistocene plunge pools, alluvial fans and deltas.

7) Shoreline—Lakes associated with coastal processes.

8) Eolian—Lakes formed by barriers formed by wind action.

9) Organic—Lakes formed by the natural accumulation of organic material.

10) Meteorite—Lakes formed by the impact of meteorites.

11) Engineered—Lakes formed by planned activities, including beaver dams and reservoirs created by man

Source for Data Standards:

Fairbridge, R.W., 1968

i. *Tectonic*

1) Fault Scarp—A steep slope or cliff formed directly by movement along a fault and representing the exposed surface of the fault.

2) Fault Trace—Formed when the original fault scarp has been destroyed, but a scarp remains along the line of the fault because rocks of differing resistance occur on opposite sides of the fault. Often visible as a lineation crossing the landscape.

3) Fault Terrace—An irregular, terrace-like tract between two fault scarps produced on a hillside by step faulting in which the downthrow is systematically on the same side.

4) Graben—An elongate, relatively depressed crustal unit or block, that is bounded by faults on its long sides.

5) Horst—An elongate, relatively uplifted crustal unit or block, that is bounded by faults on its long sides.

6) Tilted Block—An elongate block which on one end is relatively uplifted, but on the lower end is relatively depressed, which is bounded by faults on its long sides.

Source for Data Standards:

Ritter, D.F., 1986, Bloom, A.L., 1978 and Bates, R.L., and Jackson, J.A., 1987.

Geomorphology Codes

Codes are utilized by the geomorphology tables in the R-5 Ecological Unit Inventory data base. Refer to **Appendix B** for the geomorphic process codes.

REFERENCES

Bates, R.L., and J.A. Jackson (eds), Glossary of Geology, 3rd ed., American Geologic Institute, Alexandria, VA, 1987.

Bloom, A.L., Geomorphology, Prentice-Hall, Englewood Cliffs, NJ, 1978

Definitions of Surveying and Associated Terms, American Congress of Surveying and Mapping and the American Society of Civil Engineers, 1978

Dietrich, R.V., J.T. Durto, Jr, and R.M. Foose (eds), AGI Data Sheets for Geology in the Field, Laboratory and Office, 2nd edition, American Geologic Institute, Alexandria VA, 1982.

EPA Workshop to Recommend a Minimum Set of Data Elements for Ground Water Environmental Protection Agency, Washington, DC., June, 1988.

Fairbridge, R.W. (ed), The Encyclopedia of Geomorphology, Reinhold Book Corporation, New York, 1295 pp, 1968.

Freeze, R. A., and J. A. Cherry, Ground Water, Prentice-Hall, Englewood Cliffs, NJ, 1979.

Public Lands: Geological Survey Open File Report 84-787, 1984.

Hays, W. W. (ed.), Facing Geologic and Hydrologic Hazards: U. S. Geological Survey Professional Paper 1240-B, 1981.

International Union of Geological Sciences, 1989 Global Stratigraphic Chart,

Judson, S., M. E. Kauffman, and L. D. Leet, Physical Geology, 7th ed., Prentice-Hall, Englewood Cliffs, NJ, 1987.

Miller, C.D.; Potential Hazards from Future Eruptions in the Vicinity of Mount Shasta Volcano, Northern California; Geological Survey Bull. 1503, 43 pp; 1980

Miller, C.D.; Potential Hazards from Future Volcanic Eruptions in California; U.S. Geological Survey Bulletin 1847; 1989; 17pp.

National Soils Handbook, "Glossary of Landform and Geologic Terms", Soil Conservation Service, Washington, D.C., November, 1985.

Ritter, D. F., Process Geomorphology, 2nd ed., Wm. C. Brown, Dubuque, 1986.

Rosgen, D., Proceedings: Riparian Ecosystems and Their Management: Reconciling Conflicting Uses, Tucson, Arizona, April 1987, Revised 1989.

Stanley, S. M., Earth and Life Through Time, 2nd ed., W. H. Freeman, New York, 1989.

Travis, R. B., "Classification of Rocks", Quarterly of the Colorado School of Mines, Vol. 50, No. 5, Golden, CO, January, 1955.

Varnes, D.J. Slope Movement Types and Processes IN: Landslides-Analysis and Control (Schuster, R. L. and Krizek, R. J., eds.), National Academy of Sciences, Washington D.C., 1978, Chapter 2, pp. 11-33.

Varnes, D.J., Landslide Hazard Zonation: A Review of Principles and Practice; United Nations Educational, Scientific and Cultural Organization, Paris; 63 pp.

APPENDIX A

Lithology Codes

The following codes are utilized in the R-5 Ecological Unit Inventory database

ROCK TYPE	SPECIFIC LITHOLOGY	PRIMARY CODE	SECONDARY CODE
Igneous - Intrusive		I	
	Syenite		S
	Granite		GR
	Monzonite		M
	Granodiorite		GD
	Syenodiorite		SY
	Diorite		D
	Gabbro		GB
	Peridotite		PD
Igneous - Extrusive		V	
	Trachyte		TR
	Rhyolite		R
	Latite		L
	Dacite		D
	Andesite		A
	Basalt		B
	Basaltic-Andesite		BA
	Obsidian		OB
	Pumice		P
	Tuff		T
	Tephra		TE
Sedimentary		S	
	Conglomerate		C
	Breccia		B
	Sandstone		SS
	Arkose		ASS
	Graywacke		GSS
	Shale		SH
	Siltstone		SI
	Limestone		LS
	Dolomite		DO
	Tufa		TU
	Travertine		TR
	Chert		CH
	Diatomite		DI
	Phosphorite		PH
	Hematite		HE

APPENDIX A (Continued)

ROCK TYPE	SPECIFIC LITHOLOGY	PRIMARY CODE	SECONDARY CODE
	Limonite		LI
	Gypsum		GY
	Anhydrite		AN
	Halite		HA
	Peat		P
	Lignite		LG
	Coal, Bituminous		CB
	Coal, Anthracite		CA
	Asphalt		AS
Metamorphic		M	
	Gneiss		G
	Schist		SH
	Phyllite		PH
	Slate		SL
	Mylonite		MI
	Metaquartzite		MQ
	Marble		M
	Hornfels		HO
	Soapstone		SO
	Serpentine		SP
	Amphibolite		AM
	Metavolcanic		MV
	Serpentine Melange		SM
Unconsolidated		U	
	Alluvium		AL
	Colluvium		CO
	Constructed		CN
	Eolian		EO
	Glacial		GL
	Lacustrine		L
	Marine		M
	Organic		OR
	Transitional		TR

APPENDIX B

Geomorphic Process Codes

The following codes are used in the R-5 Ecological Unit Inventory database

GEOMORPHIC TYPE	PRIMARY PROCESS	SECONDARY PROCESS	TERTIARY PROCESS	QUATERNARY PROCESS	CODES T	1	2	3	4
FLUVIAL					F				
	Eroding Hillslopes					EH			
	Streambank					SB			
	Relict Stream Channel					RSC			
	Stream Channel					SC			
	Floodplain					FP			
	Stream Terrace					ST			
		Depositional Terrace					DT		
		Erosional Terrace					ET		
	Alluvial Fans					AF			
		Proximal Facies					PF		
		Medial Facies					MF		
		Distal Facies					DF		
	Bajada					BA			
		Fan Skirt					FS		
	Pediment					P			
	Bolson					BO			
GLACIAL					G				
	Erosional					E			
		Arete					AR		
		Cirque					CR		
		Horn					HR		
		Tarn					TA		
	Depositional					D			
		Drumlin					DR		
		Esker					ES		
		Kame					K		
		Kame Terrace					KT		
		Moraine					M		
			End Moraine					EM	
			Ground Moraine					GM	
			Lateral Moraine					LM	
			Medial Moraine					MM	
			Recessional Moraine					RM	
			Terminal Moraine					TM	
		Rock Glacier					RG		
		Outwash Plain					OP		
		Valley Train					VT		
		Outwash Terrace					OT		

APPENDIX B (Continued)

GEOMORPHIC TYPE	PRIMARY PROCESS	SECONDARY PROCESS	TERTIARY PROCESS	QUATERNARY PROCESS	CODES T	1	2	3	4
<u>LACUSTRINE</u>					L				
	Tectonic					T			
		Lake Plain					LP		
		Lake Terrace					LT		
	Volcanic					V			
	Landslide					LS			
	Glacial					GL			
	Solution					S			
	Fluviatile					F			
	Shoreline					SH			
	Eolian					EO			
	Organic					OR			
	Meteorite					ME			
	Engineered					EN			
<u>TECTONIC</u>					T				
	Fault Scarp					FS			
	Fault Trace					FTR			
	Fault Terrace					FTE			
	Graben					GR			
	Horst					HO			
	Tilted Block					TB			
<u>IGNEOUS INTRUSIVE</u>					II				
<u>IGNEOUS EXTRUSIVE</u>					IE				
	Volcano					V			
		Shield					SH		
		Composite					CO		
		Cinder Cone					CC		
		Spatter Cone					SC		
		Lava Cones					LC		
	Dome					D			
		Lava Dome					LD		
		Plug Dome					PD		
	Lava Flow					LF			
		AA Flow					AA		
		Pahoehoe Flow					PH		
		Block Flow					BF		
	Pyroclastic Flow					PF			
	Lahar					LH			
	Caldera					CA			
	Crater					CR			
	Lava Tubes					LT			
	Tephra Fields					TF			

APPENDIX B (Continued)

GEOMORPHIC TYPE	PRIMARY PROCESS	SECONDARY PROCESS	TERTIARY PROCESS	QUATERNARY PROCESS	CODES T	1	2	3	4
MASS WASTING					MW				
	Falls					F			
		Source					S		
		Deposit (Talus)					T		
	Topples					T			
		Source					S		
		Deposit (Talus)					T		
	Slides					S			
		Rotational					R		
			Main Scarp					MS	
			Secondary Scarp					SS	
			Bench					B	
				Eroded Bench					EB
			Toe Zone					TZ	
		Translational-Block Slides					T		
			Main Scarp					MS	
			Secondary Scarp					SS	
			Bench					B	
				Eroded Bench					EB
			Toe Zone					TZ	
		Transiational-Debris Slides					DS		
			Main Scarp					MS	
			Secondary Scarp					SS	
			Bench					B	
				Eroded Bench					EB
			Toe Zone					TZ	
		Rotational-Translational					RT		
			Main Scarp					MS	
			Secondary Scarp					SS	
			Bench					B	
				Eroded Bench					EB
			Toe Zone					TZ	
	Lateral Spreads					LS			
		Rock Spread					R		
		Earth Lateral Spread					E		

APPENDIX B (Continued)

GEOMORPHIC TYPE	PRIMARY PROCESS	SECONDARY PROCESS	TERTIARY PROCESS	QUATERNARY PROCESS	CODES T	1	2	3	4
	Flow					FL			
		Debris Flow					DF		
			Source Zone					S	
			Transport Zone					T	
			Deposit Zone					DZ	
		Debris Avalanche					DA		
			Source Zone					S	
			Transport Zone					T	
			Deposit Zone					DZ	
		Debris Torrent					DT		
		Block Stream Flow					BS		
		Solifluction					S		
		Soil Creep					C		
			Colluvial Ridgetop					CR	
			Colluvial Hillslope					CH	
			Colluvial Apron					CA	
		Earth Flow					EF		
			Main Scarp					MS	
			Secondary Scarp					SS	
			Bench					B	
				Eroded Bench					EB
			Toe Zone					TZ	
		Dry Flow					DF		
		Dry Sand Flow					DS		
			Ravel Cone					RC	
		Loess Flow					LF		
	Complex					C			
		Rock Fall Avalanche					RF		
			Source Zone					S	
			Transport Zone					T	
			Deposit Zone					DZ	
		Slump and Topple					ST		
			Source Zone					S	
			Transport Zone					T	
			Deposit Zone					DZ	
		Rock Slide-Rock Fall					RS		
			Source Zone					S	
			Transport Zone					T	
			Deposit Zone					DZ	

APPENDIX B (Continued)

GEOMORPHIC TYPE	PRIMARY PROCESS	SECONDARY PROCESS	TERTIARY PROCESS	QUATERNARY PROCESS	CODES T	1	2	3	4
		Slump-Earth Flow					SE		
			Toe Zone					TZ	
				Nested Toe Zone					NTZ
			Primary Scarp					PS	
				Nested Primary Scarp					NPS
				DS-Prone Prim Scarp					DSPS
			Secondary Scarp					SS	
			Lateral Scarp					LS	
				Nested Lateral Scarp					NLS
				DS-Prone Lateral Scarp					DSLS
			Bench					B	
				Nested Bench					NB
			Floating Block					FB	
			Sag Pond					SP	
		Internested or Multiple Rotational-Translational Slides					IRT		
		Debris Slide Basin					DSB		
		Valley Inner Gorge					IG		
			Primary					P	
			Relict					R	

APPENDIX C

Geomorphic Map Unit Connotative Legend

The following table lists the connotative map unit numbers to be used for geomorphic map units.

Geomorphic Type	Primary Process	Secondary Process	Tertiary Process	Quaternary Process	Geomorphic Map Unit Number
FLUVIAL					100 - 199
	Eroding Hillslopes				100
	Undifferentiated Stream System				105
			Active		106
				Stream Channel	106A
				Floodplain	106B
			Pliestocene		108
				Stream Channel	108A
				Floodplain	108B
	Meander Stream System				110
			Active		111
				Stream Channel	111A
				Floodplain	111B
			Pliestocene		113
				Stream Channel	113A
				Floodplain	113B
	Braided Stream System				120
			Active		121
				Stream Channel	121A
				Floodplain	121B
			Pliestocene		123
				Stream Channel	123A
				Floodplain	123B
	Confined Bedrock Stream System				125
			Active		126
				Stream Channel	126A
				Floodplain	126B
			Pliestocene		128
				Stream Channel	128A
				Floodplain	128B
	Stream Terrace				135
		Depositional Terrace			135A
		Erosional Terrace			135B
	Alluvial Fans				140
		Proximal Facies			140A
		Medial Facies			140B
		Distal Facies			140C
	Bajada				145
		Fan Skirt			145A
	Pediment				150
	Bolson				155

APPENDIX C (Continued)

Geomorphic Type	Primary Process	Secondary Process	Tertiary Process	Quaternary Process	Geomorphic Map Unit Number
<u>GLACIAL</u>					200 - 299
	Erosional				
		Arete			200
		Cirque			205
		Horn			210
		Tarn			215
	Depositional				
		Drumlin			220
		Esker			225
		Kame			230
		Kame Terrace			235
		Moraine			240
			End Moraine		240A
			Ground Moraine		240B
			Lateral Moraine		240C
			Medial Moraine		240D
			Recessional Moraine		240E
			Terminal Moraine		240F
		Rock Glacier			245
		Outwash Plain			250
		Valley Train			255
		Outwash Terrace			260
<u>LACUSTRINE</u>					300 - 399
	Tectonic				300
		Lake Plain			302
		Lake Terrace			304
	Volcanic				305
	Landslide				310
	Glacial				315
	Solution				320
	Fluviatile				325
	Shoreline				330
	Eolian				335
	Organic				340
	Meteorite				345
	Engineered				350
<u>TECTONIC</u>					400 - 499
	Fault Scarp				400
	Fault Trace				410
	Fault Terrace				420
	Graben				430
	Horst				440
	Tilted Block				450

APPENDIX C (Continued)

Geomorphic Type	Primary Process	Secondary Process	Tertiary Process	Quaternary Process	Geomorphic Map Unit Number
IGNEOUS INTRUSIVE					500 - 599 (RESERVE)
IGNEOUS EXTRUSIVE					
	Volcano				500
		Shield			501
		Composite			502
		Cinder Cone			503
		Spatter Cone			504
		Lava Cones			505
	Dome				515
		Lava Dome			516
		Plug Dome			517
	Lava Flow				525
		AA Flow			526
		Pahoehoe Flow			527
			High Relief		527A
			Moderate Relief		527B
			Low Relief		527C
		Block Flow			528
			High Relief		528A
			Moderate Relief		528B
			Low Relief		528C
		Older Flow			529
			High Relief		529A
			Moderate Relief		529B
			Low Relief		529C
	Pyroclastic Flow				535
	Lahar				540
	Caldera				545
	Crater				550
		Explosive			550A
		Collapse			550B
	Lava Tubes (Collapsed)				555
	Tephra Fields				560
HUMAN					600 - 699
	Aggregate Quarry				601
	Cinder Pit				602

APPENDIX C (Continued)

Geomorphic Type	Primary Process	Secondary Process	Tertiary Process	Quaternary Process	Geomorphic Map Unit Number
<u>MASS WASTING</u>					1000 - 1300
	Falls				1000
		Source			1005
		Deposit (Talus)			1010
	Topples				1025
		Source			1030
		Deposit (Talus)			1035
	Slides				1050
		Rotational			1055
			Main Scarp		1056
				DS Main Scarp	1056A
				Nested Main Scarp	1056B
			Secondary Scarp		1057
			Bench		1058
				Eroded Bench	1058A
				Nested Bench	1058B
			Toe Zone		1059
				Nested Toe Zone	1059A
		Translational -Block Slide			1065
			Main Scarp		1066
				DS Main Scarp	1066A
				Nested Main Scarp	1066B
			Secondary Scarp		1067
			Bench		1068
				Eroded Bench	1068A
				Nested Bench	1068B
			Toe Zone		1069
				Nested Toe Zone	1069A
		Translational -Debris Slide			1070
			Main Scarp		1071
			Secondary Scarp		1072
			Bench		1073
			Toe Zone		1074
		Rotational-Translational			1075
			Main Scarp		1076
				DS Main Scarp	1076A
				Nested Main Scarp	1076B
			Secondary Scarp		1077
			Bench		1078
				Eroded Bench	1078A
				Nested Bench	1078B
			Toe Zone		1079
				Nested Toe Zone	1079A
	Lateral Spreads				1085
		Rock Spread			1086
		Earth Lateral Spread			1087

APPENDIX C (Continued)

Geomorphic Type	Primary Process	Secondary Process	Tertiary Process	Quaternary Process	Geomorphic Map Unit Number
MASS WASTING (continued)					
	Flow				1100
		Debris Flow			1101
			Source Zone		1102
			Transport Zone		1103
			Deposit Zone		1104
		Debris Avalanche			1110
			Source Zone		1111
			Transport Zone		1112
			Deposit Zone		1113
		Debris Torrent			1120
		Block Stream Flow			1130
		Solifluction			1140
		Soil Creep			1150
			Colluvial Ridgetop		1151
			Colluvial Hillslope		1152
			Colluvial Apron		1153
		Earth Flow			1160
			Main Scarp		1161
			Secondary Scarp		1162
			Bench		1163
				Eroded Bench	1163A
			Toe Zone		1164
		Dry Flow			1170
		Dry Sand Flow			1175
			Ravel Cone		1176
		Loess Flow			1180
	Complex				1200
		Rock Fall Avalanche			1201
			Source Zone		1202
			Transport Zone		1203
			Deposit Zone		1204
		Slump and Topple			1210
			Source Zone		1211
			Transport Zone		1212
			Deposit Zone		1213
		Rock Slide-Rock Fall			1220
			Source Zone		1221
			Transport Zone		1222
			Deposit Zone		1223

Geomorphic Type	Primary Process	Secondary Process	Tertiary Process	Quaternary Process	Geomorphic Map Unit Number
MASS WASTING					
	Complex (continued))				
		Slump-Earth Flow			1230
			Toe Zone		1231
				Nested Toe Zone	1231A
			Primary Scarp		1232
				Nested Prim Scarp	1232A
				DS Prim Scarp	1232B
			Secondary Scarp		1233
				Nested Sec Scarp	1233A
			Lateral Scarp		1234
				Nested Lateral Scarp	1234A
				DS-Prone Lateral Scarp	1234B
			Bench		1235
				Nested Bench	1235A
			Floating Block		1236
			Sag Pond		1237
		Internested or Multiple Rotational-Translational			1250
		Slides			
		Debris Slide Basin			1255
		Valley Inner Gorge			1260
			Primary		1261
			Relict		1262

MAP UNIT COMPLEXES

If a geomorphic map unit is a complex, with two components each comprising more than 15% of the map unit, use the previous map unit numbers in conjunction, separated by a slash, with the prominent component listed first. As an example, a map unit complex containing 70% map unit 121A (active braided stream channel) and 30% map unit 121B (active braided floodplain) would be 121A/121B. A complex containing 60% map unit 123 (Pleistocene braided stream channel) and 40% map unit 527C (low relief pahoehoe lava flow) would be 123/527C.