CHAPTER

2

Landscapes, Geomorphology, and Site Description

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Introduction

This chapter describes information that is recorded about the overall setting and site features for a soil. This information includes the physiographic and landscape setting, geomorphological characteristics, and other information specific to the area where the soil is described. The setting and site often include information on drainage pattern, parent material, bedrock, erosion, land cover, and relationships to vegetation communities. Detailed information about describing soil profiles is provided in chapter 3.

A core mission of the National Cooperative Soil Survey (NCSS) of the United States is to reliably identify, inventory, and communicate information about soils and the earth systems of which they are a part. The Earth's surface, including the soils upon it, forms an ordered but complex mosaic, consisting of many pieces of different sizes, shapes, origins, and composition. It is a very human thing to try to make sense of this mosaic by identifying recurring patterns and to separate pieces into groups with similar form, content, and function. Depending upon a person's perspective and goals, there are infinite ways to partition the Earth's surface into meaningful subsets. A person interested in agriculture will have different management goals and examine different site criteria than someone interested in construction. The initial perspective will determine which variables are important to highlight, which can be grouped together, and which need to be separated. The NCSS has traditionally been based on multipurpose perspectives and goals that integrate aspects of agriculture, forestry, engineering applications, animal husbandry, and, in recent decades, ecosystem function and environmental sustainability. These multiple perspectives led to an assemblage of descriptive criteria and protocols rooted in earth science that were later expanded to address ecosystems and human-altered settings and features.

Geology

Among the many perspectives that can be applied, geology provides the most reliable and robust context for understanding natural earth systems, including soils, across the widest range of environments. It is a perspective that recognizes and details the primary framework upon which natural processes and humans operate. Geology largely defines the material architecture of the soil, i.e., the composition, general arrangement, and lateral extent of these materials. It helps to explain the configuration and distribution of the materials of which the soil is composed.

Geomorphology

Geomorphology is the study of landforms, the materials of which they are made, and the dynamics by which they are made and function. It is at the center of understanding what earth materials are, how they interact, how they originated, and how far they extend and where similar conditions and materials are likely to occur. It focuses on the combinations of composition, stratigraphy, shape, and topography of the materials and the geologic processes that give rise to and modify them.

Soil Geomorphology

Soil geomorphology addresses geomorphic details and dynamics at and near the Earth's surface that affect, or are affected by, soil processes and products. It specifically addresses the distribution, properties, and dynamic behavior of soils—issues that traditional geology and geomorphology do not emphasize because of scale or minimize because of perspective. These soil issues are particularly environmentally and economically meaningful because they occur at the "human-operative scale," i.e., the scale at which most land use decisions are made and applied and their consequences felt.

Soil science, particularly soil geomorphology, is based upon a robust relationship between lithology, hydrology, stratigraphy, geomorphology, and, to a slightly lesser degree, biota and climate (Wysocki et al., 2012; Schaetzl and Thompson, 2014; Buol et al., 2011). In many settings, hydrology and hydropedology dominate the physical redistribution of materials and catalyze the chemical reactions that transform earth materials (Simonson, 1959; Lin, 2012).

Boundaries and Transitions

Some parts of the landscape and the soils on them are separated from their neighbors by distinct, sharp boundaries over a lateral distance of just meters. For example, a stream terrace may be sharply separated from adjacent cliffs and talus cones by an abrupt, easily observed scarp (fig. 2-1). Other parts of the landscape and the soils on them have lateral boundaries that are very gradual and indistinct, transitioning over tens of meters or kilometers. For example, a loess mantle thins gradually with increasing distance from the source of the loess.

Figure 2-1

Distinct, sharp breaks between landforms are evident over short lateral distances, as shown by the talus cone in this canyon along the Palouse River in Washington.

Scale

Another major determinant in conveying soil and geomorphic information is the scale of interest (e.g., local, regional, global), which is established in initial survey perspectives and goals. Scale partly predetermines what is “relevant” and what is not, what must be “shown” and what cannot. A person managing a 1-hectare homesite has different information needs and relevancies than a regional planner who evaluates and manages a city or State. The scale of interest can be quite different for different users, and the appropriate level of information to be collected and delivered differs with the scale. At regional scales, it is typically appropriate to evaluate and emphasize landscapes and very large, constituent landforms and to minimize smaller landforms and microfeatures. For example, in an order 3 reconnaissance survey, dune fields, mountain ranges, or bolsons may be evaluated. Conversely, for localized surveys, it is typically necessary to focus primarily on smaller landforms, microfeatures, or pieces of landforms and to give only nominal attention to landscapes. For example, in an order 1 survey, barchan dunes, slip faces, or head slopes may be evaluated. The provisional soil survey of the Outer Banks of North Carolina, at a scale of 1:12,000 (USDA-SCS, 1977) is an example of a localized survey that presents the setting in considerable detail.

Digital Soil Mapping and Scale

Widely available GIS tools and digital soil mapping methods have made it much easier to move between scales. For example, geospatial information that was previously constrained by scale may be combined or split apart (see chapter 5). It is now possible to produce: (a) primary surveys capable of spanning a much wider range of scale, and (b) derivative or second-generation resource maps from a primary spatial database that span wider ranges of scale than the initial survey. The capability to move between scales must coincide with primary data that accommodates such changes in scale. For example, traditional soil inventories were made based upon stated, relatively narrow spatial scales (e.g., order 2 or 3). The initial field data collected, assigned classes, spatial separations (e.g., polygons), interpretations, and other information remain constrained by the rules and decisions for the scale at which they were originally developed. It is typically possible to aggregate data upwards in scale with a minimal impact on information integrity. It is much more challenging to do the opposite and legitimately disaggregate primary data to create finer resolution information. With new tools, software, and statistical methods, it is possible to produce information with finer resolution using disaggregation techniques. However, the original data, metadata, and inherent decisions made at the original inventory scale remain determinate; those original biases will persist across scales. Some morphometric parameters, such as slope, can be readily replaced or enhanced with higher resolution information, such as LiDAR. In some cases, such as the separation of soil bodies at finer resolution, previous information can be more problematic and new supporting data appropriate to the new scale may be needed.

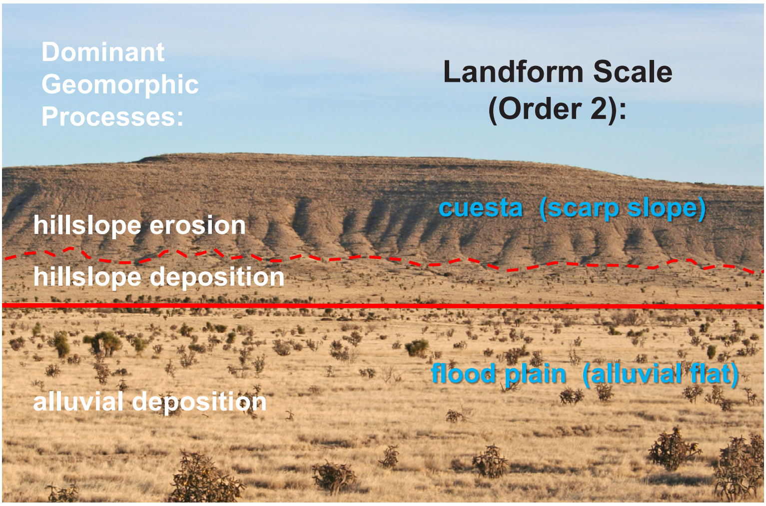
Capturing Soil-Landscape Relationships at Various Scales

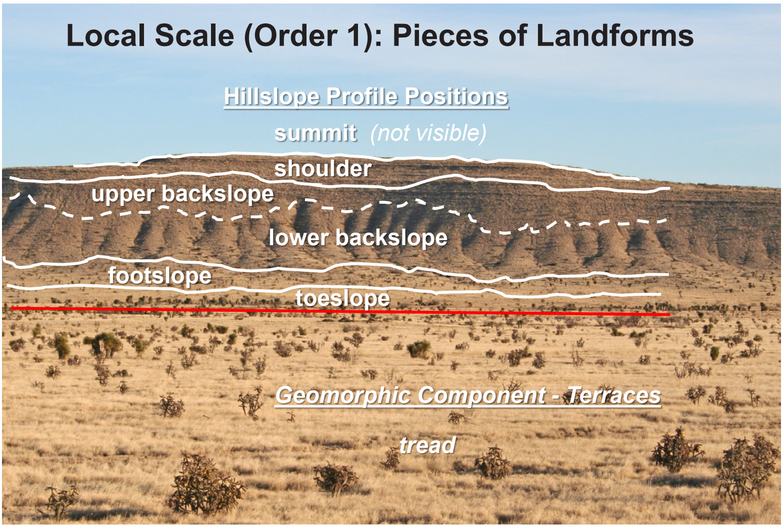
It is typically impractical or financially prohibitive to make an ideal number of field observations. Consequently, representative observation sites need to be chosen wisely and used to extrapolate to areas that cannot be visited. Observation efficiency can be greatly enhanced by developing soil-landscape models that capture recurring spatial relationships. Part of such model development includes selecting an appropriate scale. As discussed previously, scale determines what can and cannot be shown. Robust soil-landscape models are subject to incremental changes and refinements that reflect the accumulation of knowledge and data during the progression of the survey.

A site may have one of three common scales of models: a large area or catchment (landscape) scale, a hill (landform) scale, and a hillslope position or pedon (microfeature) scale. The appropriateness of each scale depends upon the perspectives and objectives of the survey. Each scale can be applied, but each conveys somewhat different information and has different strengths and limitations. For example, for a setting along the border of the Gypsum Plains State Physiographic Area in Culberson County, Texas, a series of hierarchical (nested) landscape models can be developed and applied. At a landscape scale, the area presents eroded structural hills and alluvial plains. The dominant geomorphic processes are tectonic and erosional (and, to a minor extent, fluvial) and are regional in scope. At a landform scale (fig. 2-2, top image), which is finer than landscape, the same area presents an eroded, structural hill (questa) and valley floor (alluvial flat). The dominant geomorphic processes are erosional and fluvial and are local in scope. At a microfeature scale (fig. 2-2, bottom image), the area presents discrete subsets within landforms. The dominant geomorphic processes are hillslope erosion and deposition (slope wash processes) and fluvial modification (alluvial deposition processes) and are very localized in scope. Different scales yield different information.

Hillslope-scale processes commonly express themselves differently at different positions (i.e., summit, shoulder, upper slope or backslope, footslope, and toeslope). Each hillslope position represents a process-dominated area, as demonstrated by a progressive reduction of rock fragment size across the ground surface from the summit to the toeslope position (fig. 2-3).

Figure 2-2





A scarp slope of a cuesta above an alluvial flat. Scale determines which geomorphic descriptors can be effectively used and presented. Geomorphic evaluations of regional scope (landscape scale) can separate tectonic hills from areas dominated by fluvial processes (not shown). The more localized, landform scale can differentiate dominant landforms (cuesta and alluvial flat) and the dominant geomorphic processes that control them within the landscape (top image). More detailed erosional and depositional surfaces derived from dominant hillslope processes need to be represented at a finer scale. These include microfeatures (e.g., ribs and groves), hillslope profile positions (e.g., summits and shoulders), and geomorphic components (e.g., components of terraces or hills, such as nose slopes, head slopes, and side slopes; not shown).

Figure 2-3

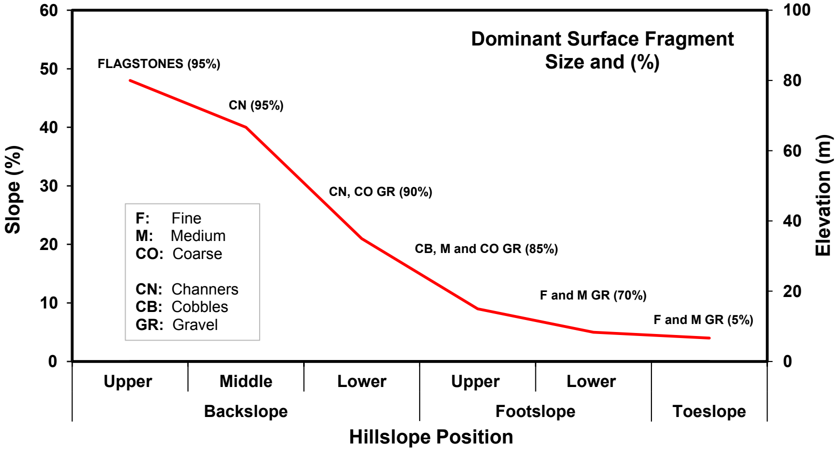
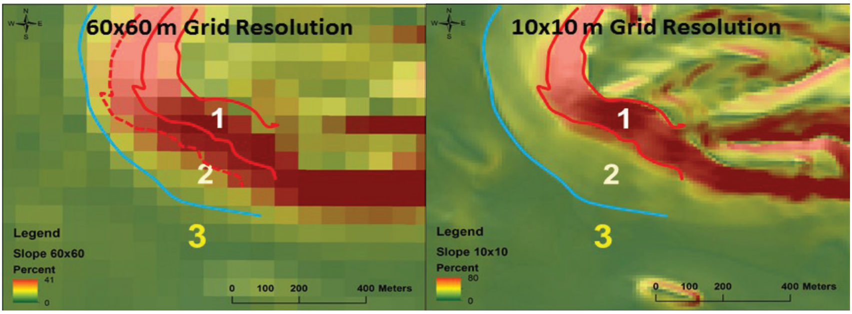


Diagram of the change in surface fragments along a transect of a scarp slope on a cuesta in Culbertson County, Texas. The progressive reduction in dominant size and percentage as one moves down slope demonstrates the impact of hillslope processes at a local level. On the upper backslope, dominant erosional hillslope processes are evidenced by the presence of flagstones on the surface. On the middle and lower backslopes, the percentages and sizes of surface fragments (channers and others) are indicative of lateral transport. On the lower footslope and toeslope, rock fragments are dominantly medium and fine gravel with decreasing percentages. They are indicative of deposition processes.

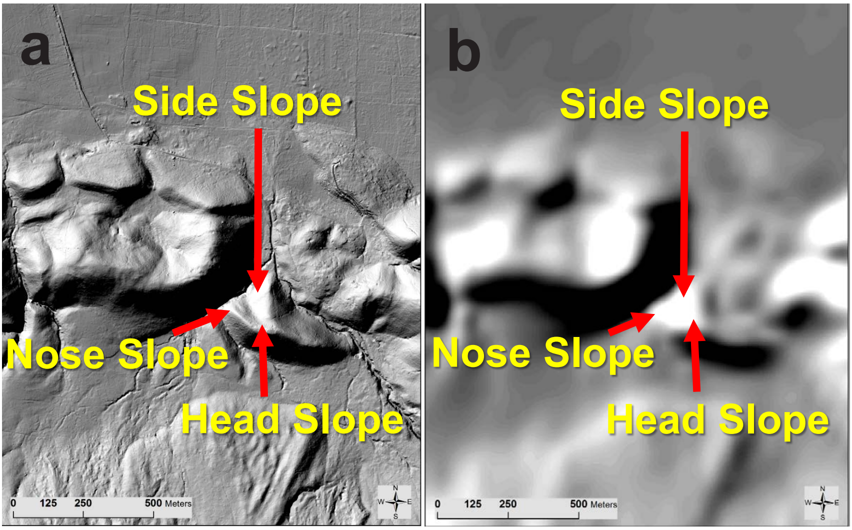
Figure 2-4



A comparison of digital maps with 60 x 60 m (left) and 10 x 10 m (right) grid sizes demonstrates the detail at different resolutions. The 60 x 60 m grid visually captures the three major landform units but not the geomorphic components of hills, namely nose slope, side slope, and head slope. An even finer resolution, such as LiDAR elevation data, is needed to capture the physical expressions of very localized hillslope processes.

In the digital environment, grid scales can be used to determine which resolution best captures important attributes for landscape modeling. What is apparent at one scale may not be apparent at another (fig. 2-4). Digital smoothing techniques, while appropriate for some analyses, can adversely affect the ability to identify features at a given scale (fig. 2-5).

Figure 2-5



Images showing changes in slope class interpretation as affected by digital elevation model (DEM) resolution from LiDAR. Image a—Grid size (1 x 1 m) captures surface features nested within hillslope position. Image b—As resolution decreases (30 x 30 m) and surface becomes digitally smoother, the geomorphic components of hills (nose, side, and head slopes) are no longer visible.

Placing Soil-Landscape Relationships in Their Proper Context

Soil geomorphology can be used effectively to evaluate, recognize, and communicate the context (setting) of natural systems. Context is key to:

1. Recognizing and understanding the materials and processes occurring at a given location or area.
2. Effectively predicting the distribution of materials that dominate the area. Commonly, the first and most useful question is “Where

are you on the planet?" (i.e., the geomorphic context rather than the geographic coordinates).

3. Recognizing the dynamic processes and relationships active between and within soils and land areas.

Development Stages for Soil-Landscape Models: Expectations vs. Reality

Developing accurate landscape models begins with using expert knowledge and experience to anticipate and portray relationships between landscapes, geomorphic systems, and soils. In whatever form, an initial model must be rigorously tested ("ground-truthed") and revised as needed to accurately reflect actual, observed relationships of soils and landscapes.

Developing Initial Soil-Landscape Models

It is helpful for scientists to have a general expectation of what they will encounter in an area or at a given site. For example, if the site is in a river valley, it is reasonable to expect that the site will reflect fluvial dynamics and features in the landforms, sediments, and soils of the area. The location of the site within the river valley (e.g., headwaters vs. delta) can further refine preliminary expectations. Headwater fluvial sediments, and the soils that formed in them, may be expected to contain more, larger, and less rounded coarse fragments, be somewhat less well sorted, and have less contrasting sediment strata than fluvial sediments in a delta. In addition, general conditions and dynamics for a water table might be anticipated (e.g., gaining stream vs. losing stream) based on the prevailing climate. A preliminary model can provide a tentative framework in which scientists can begin to efficiently investigate, understand, and give order to a diverse natural world. In the digital world, this now includes considerable pre-mapping, based primarily upon improved, detailed digital elevation models and existing information (see chapter 5). Preliminary soil-landscape models are helpful. The adage "If I hadn't known about it, I wouldn't have recognized it" is a relevant and practical truth. The more one understands a natural system, the easier it becomes to recognize the physical expressions of those systems.

Describing and Recording What is Actually There

Although soil-landscape models can be very useful at any stage of soil inventory, it is critical that a scientist maintain an open mind and adjust models as new information becomes available. A common error by field workers is to continue to defer to a preconceived expectation, such as a preliminary landscape model, rather than to adapt their ideas based on what is actually encountered. If a landscape model fails to match the natural features and sediments actually found, it must be modified or abandoned. A useful model should fit the facts, not the reverse.

Consistently Describing Landscapes, Landforms, and Geomorphology

There are various major kinds of information typically gathered to identify, evaluate, or communicate geomorphic information. A descriptive system and set of terms that can be used consistently are important for conveying the information accurately between individuals and making valid comparisons from place to place. The NCSS generally uses the Geomorphic Description System, or GDS (Schoeneberger and Wysocki, 2012). The system consists of three main sections:

Physiographic location.—A named geographic area is specified with a defined location.

Geomorphic description.—A discrete land surface feature (a separate entity) or an assemblage of features is identified. Features are categorized by dominant process of origin or geomorphic setting.

Surface morphometry.—Land surface shape or geometry is described. A discrete portion of a geomorphically defined land feature, area, or slope segment is identified. Microrelief, drainage patterns, and other surface features are also described.

Geographic and Physiographic Information

Geographic and physiographic information primarily addresses the question “Where is it?” It identifies the specific location of an area on the planet (e.g., the Appalachian Mountains). This information has powerful communication value to a wide range of people. Most people can relate a geographic name to some understanding of an area. Fewer users appreciate explicit technical descriptions (e.g., an eroded, folded, paleo-continental margin mountain system). The Appalachian Mountains and the Rocky Mountains are both mountain systems in the geomorphic sense, yet they differ in important geographic locations as well as geomorphic details. Their names emphasize geographic differences, not the geologic composition or type of mountains. Geographic and physiographic names may or may not accurately reflect the actual geomorphology. Confusion can arise if geographic names include geomorphic terms that do not adhere to their technical geomorphic meaning. For example, an area geographically identified as Thompson's Bench may geomorphically be something other than a true structural bench, such as a stream terrace or a horst.

Physiographic information combines geographic information with limited geomorphic information to describe location. In physiography, distinctions in topography, bedrock or parent material, watersheds, and other attributes are used to group geomorphically similar or related areas. Experience has consistently demonstrated that physiographic information is the most robust, versatile, and least ephemeral basis for describing and partitioning the landscape mosaic. Other location approaches emphasize spatial distinctions based on something other than physiography. For example, some approaches emphasize natural ecological environments or land management systems. The most appropriate descriptive framework for location is determined by the survey perspectives and goals.

Physiographic Location

Because there are numerous and diverse users of soil survey information, there are various perspectives and objectives. A single scale of information cannot best serve all of them. A homeowner has different needs and interests than a regional planner or a resource management government agency with national scope. Information on physiographic location can be usefully partitioned within a generalized hierarchy of scale (table 2-1). In the United States, the highest three levels are based on work by Fenneman (1957) for the conterminous U.S. and by Wahrhaftig (1965) for Alaska. Additional lower levels describe physiographic areas within States and more localized areas.

Table 2-1

Physiographic Location, Relative Scale (in Descending Order) and Examples in the U.S.

Physiographic location level	Relative scale	Example*
Physiographic division	Continental scale	Interior Plains
Physiographic province	Regional scale	Central Lowland
Physiographic section	Sub-regional scale	Wisconsin Driftless Section
State physiographic area	State scale	Wisconsin Dells
Local physiographic name	Local scale	Blackhawk Island

* Progressive levels of detail.

Maps are available for the three upper physiographic levels from Fenneman (1957). They are reproduced in the *Geomorphic Description System* (Schoeneberger and Wysocki, 2012). Maps of State physiographic areas are generally available through State Geological Survey offices or from the local university NCSS cooperators. Information on local physiographic names is primarily obtained from U.S. Geological Survey topographic quadrangle maps, where available.

Geomorphic Description

Geomorphic description attempts to answer the questions "What is it?" and "How did it occur?" for natural features and sediments. Earth surface features can be effectively arrayed in various ways for particular needs. Two ways that complement one another are: (1) master lists loosely stratified by scale into landscapes, landforms, and microfeatures, and (2) lists arrayed by geomorphic environment (fluvial, eolian, etc.).

Scale

Earth surface features can be partitioned into any number of scale ranges, but three general levels have proven consistently effective: landscapes, landforms, and microfeatures.

Landscapes, features at the coarsest scale, are collective groups or families of related landforms and typically cover large areas. Examples are a mountain range and canyonlands (fig. 2-6). They are most important to general or reconnaissance surveys (order 3 or 4, see chapter 4).

Figure 2-6

A canyonlands landscape in the San Rafael Swell, Utah.

Landforms are discrete, individual features that are related to one another within the context of the larger landscape and can be mapped at conventional mapping scales, such as order 2 (fig. 2-7). They are typically local in size, but some can be quite large. It is helpful to remember that natural and anthropogenic landforms and microfeatures can be expressed as the result primarily of removal, transport, or deposition. For example, blowouts and borrow pits are the result of removal, longshore bars and active dunes are the result of transport, and alluvial fans and dredge spoils are the result of deposition.

Figure 2-7

Loess hill and river valley landforms in western Iowa, along the Missouri River.

Microfeatures are discrete, individual, earth surface features that are readily identifiable on the ground but are too small or intricate to display or capture at conventional mapping scales. Examples are vernal pools and turf hummocks (fig. 2-8). Where present, these mini-landforms can have substantial impact on internal water flow, soil development, natural ecosystems, and land management.

There are many choices within each of these major categories, particularly landforms. The choices within each category are commonly arrayed as alphabetized master lists, which are particularly appropriate for databases. Because of the huge number of choices, it is helpful to use subsets for the three main categories, arranged by geomorphic environment or other groupings of commonality.

Figure 2-8

Turf hummock microfeatures in a wet meadow in Oregon.

Geomorphic Environment

A geomorphic environment is a natural setting dominated by a geomorphic process of formation and modification and the resultant behavioral dynamics. For example, a fluvial geomorphic environment consists of landforms and associated sediments created directly by, or in response to, channel water flow (fluvial processes). In such a setting, present-day environmental dynamics, such as ground-water and water table dynamics, are likely to be largely controlled by the fluvial system that formed the area's landscape. Table 2-2 lists the prominent geomorphic environments that are most relevant to soils in the United States and extensive elsewhere in the world.

Multiple Geomorphic Processes

Sites may have evidence of more than one geomorphic process. Typically, these processes are not equal. One process tends to dominate a given land area, and other processes, if present, have a minor presence and influence. It is important to recognize the most pervasive process and its products because they establish the primary landscape configuration and sediment composition. It is also important to recognize secondary processes and their sediments where they substantively affect soils. For

Table 2-2

Prominent Geomorphic Environments and Processes in the U.S. and Examples

Geomorphic environment or other setting	Dominant process or attributes	Examples * LS = Landscape LF = Landform Micro = Microfeature
Coastal marine & estuarine	Wave or tidal control; areas near shore, shallow submarine areas	LS: coastal plain LF: nearshore zone Micro: shoreline
Lacustrine	Related to inland water bodies	LS: lake plain LF: lakebed Micro: strandline
Fluvial	Concentrated channel flow	LS: river valley LF: stream terrace Micro: bar
Solution	Dissolution and subsurface drainage	LS: cockpit karst LF: sinkhole Micro: solution corridor
Eolian	Wind related (erosional and depositional)	LS: dune field LF: barchan dune Micro: slip face
Glacial	Directly related to glaciers (glaciofluvial, etc.)	LS: till plain LF: ground moraine Micro: tarn
Periglacial	Non-glacial, cold climate (modern or relict)	LS: thermokarst LF: patterned ground Micro: stripe
Mass movement	Gravity	LS: breaklands LF: landslide Micro: sag
Volcanic & hydrothermal	Volcanic and/or hydrothermal processes	LS: volcanic field LF: lava flow Micro: tumulus
Tectonic & structural	Regional and local tectonic processes or crustal movement	LS: mountain range LF: graben Micro: sand boil

Table 2-2.—continued

Geomorphic environment or other setting	Dominant process or attributes	Examples * LS = Landscape LF = Landform Micro = Microfeature
Erosional	Dominated by hillslope and sheet-wash processes (non-concentrated channel flow)	LS: breaklands LF: pediment Micro: gully
Wetlands	Vegetated and/or shallow wet areas and wet soils	LS: Everglades LF: mangrove swamp Micro: vernal pool
Water bodies	Surface water features; primarily open water	LS: ocean LF: oxbow lake Micro: pond
Subaqueous features	Permanently submerged features that support plant life or adjacent areas	LS: lagoon LF: lagoon bottom Micro: shoal

* For complete choice lists, see *Geomorphic Description System* (Schoeneberger and Wysocki, 2012).

example, loess commonly mantles till plains in continental glaciated environments. If the loess cap is relatively thin, the dominant and most important geomorphic context is glacial because it explains the prevailing land features, topography, and unconsolidated materials. The loess should be recognized for what it is, and not some other geologic deposit, and correctly identified and described in the soil stratigraphy. If the loess cap is thick, it can supersede underlying glacial materials and function as the determinant geomorphic setting itself, such as loess hills. Although very thin (e.g., ≤ 25 cm) surficial sediments are prone to mixing by normal pedologic processes, to the point that they lose their identifying depositional morphology, they can still have an important influence on the soil. In this case, these materials may be identified even though their geomorphic process is not recognized overtly. Loess-influenced colluvium is an example.

Some geomorphic descriptive systems attempt to capture both primary and secondary geomorphic processes at a site. This approach, which may be appropriate for mapping geomorphology, can become complex and confusing when addressing soil geomorphology in the context of soil inventory. The main objective of soil inventory is to address the geomorphic processes and products that directly or substantively influence soils and soil behavior. Larger scale or deep-seated geomorphic processes that do not directly or substantively affect soils, such as deep-seated tectonic or structural phenomena, may be beyond the scope of soil inventory. This information can be included with the physiographic information or in general discussions.

Generic vs. Specific Geomorphic Terms

There is considerable range in the specificity of geomorphic terms. Some terms are very generic (e.g., uplands) and can be useful especially at the coarsest scales. While technically correct, generic terms convey relatively little information. Other terms are more specific (e.g., fault-block mountains). As a general rule, it is better to be more explicit than less. A specific term is more informative than an equally correct but more generic term. For example, "loess hill" provides more information than "hill."

Nested Features

The focus in geomorphic description is commonly the land feature (i.e., a single landform or a dominant landscape) that is most critical to soils and that conveys the most relevant context of that site or area. An example is "Alpha soil occurs on a dune." The foremost feature should be the one that most directly impacts or defines the soil. In some environments, there are multiple landforms of different scales that are each relevant to soil behavior and important in documenting an area. For these, multiple landforms can be used in sequence (nested) to convey important setting information. An example is "Alpha soil occurs on a dune on a stream terrace." If nested terms are used, typically no more than two or three are necessary.

Anthropogenic Features

Historically, soil survey in the United States has focused on natural processes, associated sediments, and resulting surface features, such as landscapes, landforms, and microfeatures. Human-altered surface features and materials were traditionally excluded or minimally recognized. They were considered to be artificial phenomena, unpredictable in composition and occurrence, and largely outside the scope of natural process-based soil survey. In recent years, however, there has been a growing awareness and acceptance of the impact of humans upon natural systems and associated features and materials. Anthropogenic features and materials differ from natural phenomena in their origin and processes of formation but can be surveyed in ways similar to those used for conventional geomorphic entities. For example, they can be identified by recurring surface expression (form and arrangement), range of composition and internal arrangement, and lateral extent. As with natural landforms and materials, the ability to consistently partition anthropogenic features into meaningful subsets facilitates recognition of anthropogenic soil geography and greatly assists in land management decisions that concern them.

Terms describing anthropogenic features were adopted by the NCSS in 1993. A new geomorphic category was established to accommodate human-altered or -created features of all scales and to elevate their recognition to the same stature as natural features (Schoeneberger and Wysocki, 2012). Since then, appreciation of the extent of human alterations of the Earth's surface has continued to evolve. As the number and variety of recognized anthropogenic features increased, proposals were made to divide anthropogenic features into three subsets loosely analogous to partitions of naturally derived earth surface features (Schoeneberger and Scheyer, 2005; Schoeneberger et al., 2012). Furthermore, the International Committee on Anthropogenic Soils (ICOMANTH, 2012) defined the phrase "anthropogenic feature" in a non-geomorphic context (any artificial artifact, mark, mold, impression, etc.). Subsequently, "anthropogenic features" (geomorphic context) has been replaced with three new, loosely scale-dependent categories: anthroscapes, anthropogenic landforms, and anthropogenic microfeatures.

An *anthroscape* is important both for its evocative simplicity as a term and its explicit recognition of human-modified lands as legitimate and significant areas. These lands are substantially different from natural systems because they have different sediments, arrangements of sediments, and water dynamics and subsequently require different management practices. An anthroscape is a human-modified "landscape" of substantial and permanent alterations formed by the removal, addition, or reorganization of the physical shape and/or internal stratigraphy of the land. It is associated with management for habitation, commerce, food or fiber production, recreation, and other human activities that have substantively altered water flow and sediment transport across or within the regolith. Types of anthroscapes include urban, suburban, reclaimed land, and agricultural.

An *anthropogenic landform* is a discrete, human-made "landform" on the Earth's surface or in shallow water that has an internal composition of unconsolidated earthy, organic, human-transported materials, or rock. It typically has straight line boundaries or geometric shape. It is the direct result of human manipulation or activities. It can be mapped at common soil survey scales, such as order 2 (> 1:10,000 to < 1:24,000). Anthropogenic landforms can originate from deposition (e.g., an artificial levee) or removal (e.g., a quarry; fig. 2-9).

Figure 2-9

Quarries are an example of an anthropogenic landform.

An *anthropogenic microfeature* is a discrete, individual, human-derived form on the Earth's surface or in shallow water that has a range in composition of unconsolidated earthy, organic, human-transported materials, or rock. It typically has a recognizable human-imposed shape. It is the direct result of human manipulation or activities. It typically cannot be mapped at common soil survey scales, such as order 1 (< 1:10,000) but can be observed locally. Anthropogenic microfeatures can originate from deposition (e.g., a conservation terrace; fig. 2-10) or removal (e.g., a ditch).

Ideas of anthropogenic features will continue to evolve and grow in coming years. The proposal to recognize a new geologic age—the Anthropocene—continues to gain support and reflects this overall trend. Information on composition, occurrence, and behavior of anthropogenic features and materials, despite their unique differences from "natural" geomorphic phenomena and processes, can assist in wise land management.

Figure 2-10

Soil conservation terraces are an example of an anthropogenic microfeature.

Surface Morphometry

Surface morphometry uses various terms to describe land surface shape or geometry, discrete portions of a geomorphic entity or slope segment, and miscellaneous features that are fundamental to soil and natural resource inventory. Several terms are discussed in the following paragraphs.

Elevation is the height of a point on the Earth's surface, relative to mean sea level. This information is widely available from common GIS databases and historically from topographic maps. Elevation conveys the important climatic context and reflects the relative potential and kinetic energy available at a location.

Soil slope has a scale connotation. It refers to the ground surface configuration for scales that exceed about 10 meters and range up to the landscape as a whole. It has gradient, complexity, length, and aspect. The scale of reference commonly exceeds that of the pedon and should be indicated. It may include an entire map unit delineation, a soil component within the map unit delineation, or an arbitrary area. Most commonly, slope is recorded in pedon descriptions for the segment of the landscape extending a few tens of meters above and below the site of the soil profile described and is representative for the landscape segment occupied by the soil component at that site.

Slope aspect is the compass bearing that a slope faces looking down slope. It is recorded either in degrees, accounting for declination, or as a general compass orientation. The direction is expressed as an angle between 0 and 360 degrees (measured clockwise from true north) or as a compass point, such as east or north-northwest.

Aspect can substantially impact local ecosystems. The impact generally increases as slope gradient and latitude increase. In the mid latitudes of the conterminous United States, this effect becomes particularly important on slopes of approximately 6 to 8 percent or greater. Increased or decreased solar radiation on slopes due to aspect can affect water dynamics across a site (fig. 2-11). In the northern hemisphere, north-northeast aspects reduce evapotranspiration and result in greater soil moisture levels, improved plant growth and biomass production, higher carbon levels, and improved drought survival rates for plants. Increased solar radiation on south-southwest aspects increases evapotranspiration and decreases biomass production, seedling survival rates, and drought survival rates for plants.

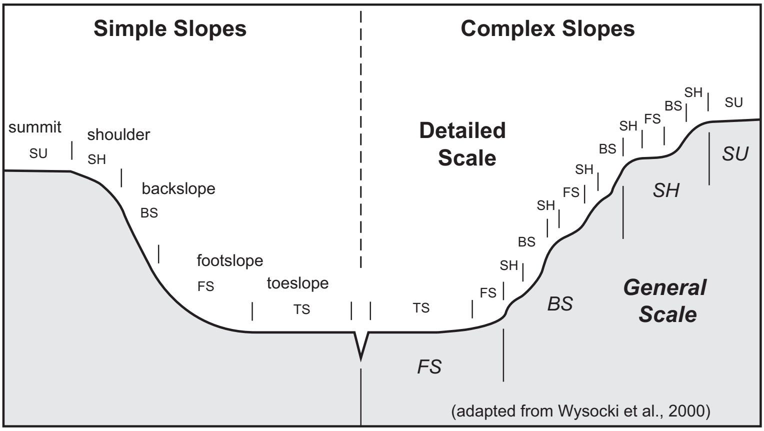
Figure 2-11

Effect of slope aspect on vegetation and tree seedling survival. (Photo courtesy of Kerry Arroues)

Slope gradient is the inclination of the land surface with respect to the horizontal plane. It is also commonly referred to as “slope percent” or simply “slope.” It is calculated as the vertical distance divided by the horizontal distance (“rise over run”), multiplied by 100, determined at a point along a line oriented up and down slope. It directly controls the kinetic energy, erosive power, and sediment carrying capacity of running water (as overland flow or channel flow), all of which increase with increasing gradient. It inversely affects the amount of time that internal soil water is present. Many soil conservation practices, such as conservation terraces, are designed primarily to reduce slope gradient to minimize soil erosion and increase infiltration. Slope gradient also directly affects land management practices by limiting ranges of operation for various types of equipment, such as tractors and log skidders.

Slope complexity is the relative linearity or smoothness (simple) or irregularity (complex) of the ground surface leading down slope and through the point or map unit of interest (fig. 2-12). Simple slopes allow the maximum slope length with comparatively unimpeded slope wash processes. In contrast, complex slopes are composed of a series of steps commonly associated with bedrock-controlled benches or other stepped surfaces (fig. 2-13). These localized breaks in slope reduce slope length, alter slope wash processes, and commonly correspond to changes in soil types.

Figure 2-12



(adapted from Wysocki et al., 2000)

Simple versus complex slopes and slope positions. Note the choice of a detailed or general scale approach to slope position for complex slopes (right side).

In many places, internal soil properties are more closely related to the slope complexity than to the gradient. Slope complexity has an important influence on the amount and rate of runoff and on sedimentation associated with runoff. It can also affect soil temperature through local variation in soil aspect.

Traditionally, slope (gradient) classes are assigned to soil map units to convey the dominant range of slope gradients occurring within it. The numerical slope class limits of map units are not always consistent within or between survey areas. They can vary from one survey area to another, to better capture the local survey slope conditions, as long as they

Figure 2-13

Complex slopes on a hillslope of interbedded sedimentary rocks in Wildcat Hills, Nebraska.

generally remain within the maximum (upper) and minimum (lower) class limits (table 2-3). Descriptive adjectives corresponding to specified slope ranges can be used in text. Such adjectives are slightly different for the mid-range slope classes, depending upon whether the dominant slopes are simple or complex (table 2-3). Gently sloping or undulating soil map units, for example, can be defined with slope class ranges as broad as 1 to 8 percent or as narrow as 3 to 5 percent. Classes may exceed the broadest range indicated in table 2-3 by one or two percentage points where the range is narrow and by as much as 5 percent or more where the range is broad. The slope class terms can also be used in naming slope phases of map units, as discussed in chapter 4.

If the detail of mapping requires slope classes that are more detailed than those in table 2-3, some or all of the slope classes can be subdivided as follows:

Nearly level.—Level, nearly level
Gently sloping.—Very gently sloping, gently sloping
Strongly sloping.—Sloping, strongly sloping, moderately sloping
Undulating.—Gently undulating, undulating
Rolling.—Rolling, strongly rolling

Table 2-3

Definitions of Slope Classes

Classes for—		Recommended slope (gradient) class limits	
Simple slopes	**Complex slopes**	**Lower (percent)**	**Upper (percent)**
Nearly level	Nearly level	0	3
Gently sloping	Undulating	1	8
Strongly sloping	Rolling	4	16
Moderately steep	Hilly	10	30
Steep	Steep	20	60
Very steep	Very steep	> 45	

In a highly detailed survey, for example, slope classes of 0 to 1 percent and 1 to 3 percent would be named "level" and "nearly level," respectively.

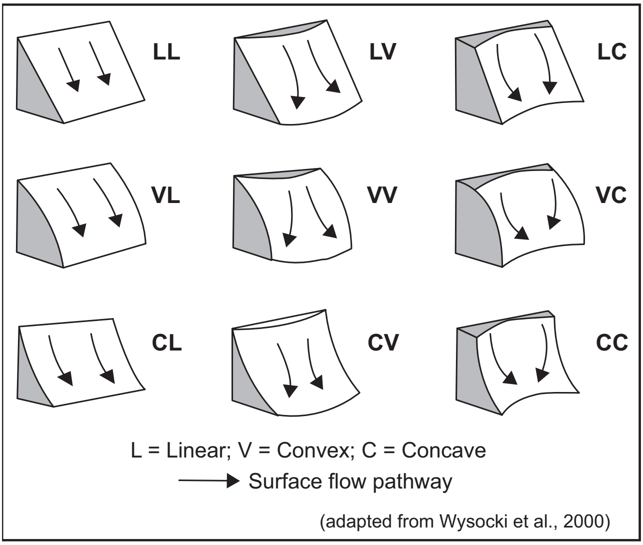
Slope length is rarely used directly in soil mapping because its range across all the polygons of a soil map unit is highly variable. Furthermore, natural slope lengths are commonly interrupted and artificially shortened by human-made features such as ditches, roads, or field boundaries. Slope length does have important uses in key soil erosion programs and models, including the Revised Universal Soil Loss Equation, version 2 (USDA-NRCS, 2016d). It has considerable control over surface water runoff and potential for accelerated water erosion. Generic terms such as "long" or "short" can be used to describe slope lengths that are typical of certain kinds of soils. These terms are typically relative within a physiographic region. A "long" slope in one place might be considered "short" in another. If such terms are used, they are defined locally. For observations at a particular point, it may be useful to record the length of the slope that contributes water to that point (called *point runoff slope length*) as well as the total length of the slope. The *sediment transport slope length* is the distance from the expected or observed initiation point upslope of runoff to the highest local elevation where deposition of sediment is expected to occur. This distance is not necessarily the same as the point runoff slope length.

Relative slope segment position indicates vertical subdivisions of long slopes. It can be useful, especially in areas of substantial slope length, to identify general "slope segment" positions, such as lower third, middle third, and upper third. For example, the long slopes of mountainflanks commonly exhibit changes in bedrock stratigraphy somewhere along the slope that correspond to soil types that differ in parent material composition and type and amount of rock fragments.

Slope shape is the dominant form of the ground surface curvature. It is expressed in two directions, which are paired (fig. 2-14): up and down slope (vertical, or perpendicular or normal to the slope contour) and across slope (horizontal, or along the slope contour). When used in tandem, the slope directions describe the configuration of the surface of a portion of the slope and the soil upon it. Both slope directions can be described by one of three curvature shapes: convex, linear, or concave. In the up and down direction, the surface of a linear slope is substantially a straight line when seen in profile at right angles to the contours. The gradient neither increases nor decreases significantly with distance (fig. 2-14, top row). An example is the dip slope of a cuesta. On a concave slope (fig. 2-14, bottom row), gradient decreases down the slope. An example is a footslope. Where the slope decreases, runoff water decelerates and tends to deposit sediments, as on the lower parts of the hillslope. Simultaneously, as surface water flow slows, it has greater opportunity to infiltrate into the soil. On a convex slope, such as the shoulder of a hill or ridge, gradient increases down the slope and runoff tends to accelerate as it flows down (fig. 2-15, middle row). If contours are substantially straight lines (parallel), as on the side of a lateral moraine, the across slope shape is linear. An alluvial fan has a convex contour that bows outward. A cirque has concave contours. In figure 2-15, nine possible combinations of linear (L), concave (C), and convex (V) slopes are shown. For both the up and down orientation and the across slope orientation, where the slope is convex (fig. 2-14, middle column), surface runoff water tends to diverge (spread apart) as it moves down the slope. As a result, overland flow is dissipated and both the erosive power and the amount of water available for infiltration are reduced. Where the slope is concave, surface runoff water tends to converge, or concentrate (fig. 2-14, right column). The most intense concentration of running water occurs where both orientations are concave, as in a swale on a hillside or in a head slope at the head of a drainageway (fig. 2-15). The most intense divergence of running water occurs where both orientations are convex, as on a nose slope at the end of a ridge (fig. 2-15).

Hillslope profile positions (also called *hillslope positions*) refer to two-dimensional segments of a line used to describe slope position along a transect oriented up and down slope (normal to the slope contour). They do not address lateral dimensions. These line segments, progressing from the top of the slope to the bottom, are: summit, shoulder, backslope,

Figure 2-14



(adapted from Wysocki et al., 2000)

Slope shape based on combinations (up and down slope and across slope) of surface curvature.

footslope, and toeslope (see fig. 2-12). These terms have proven useful for many decades because they can describe areas on slopes where soil bodies are consistent and breaks in slope curvature where soils typically change. They can be used alone or in a combination to verbally capture where soils recur up and down slopes.

Geomorphic components are similar to hillslope profile positions (up and down slope) but include an additional lateral dimension (across slope) that enables distinctions to be made between the slope curvatures of land areas in three dimensions. They indicate patterns of surface water flow, such as concentration, dispersion, or parallel (lateral) flow. Not all settings, however, share the same, recurrent configurations. For this reason, geomorphic component descriptors have been developed for four different settings: hills, terraces and stepped landforms, mountains, and flat plains (tables 2-4 to 2-7 and figs. 2-15 to 2-18).

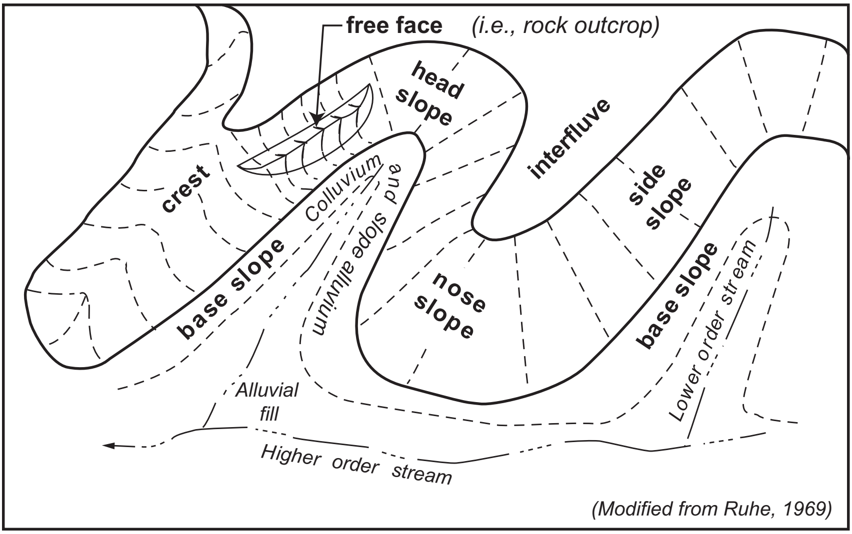
As with hillslope profile positions, geomorphic components for hills have been widely used in one form or another. These terms and concepts work very well for partitioning and describing hilly terrain as functionally distinct members. However, these same concepts work poorly when applied to very gentle terrain. The kinetic energy of running water is dramatically and functionally less at low gradients. The erosive

Table 2-4

Geomorphic Component Terms for Hills

Geomorphic component term	Typical attributes
Interfluve	High, relatively level area that generally does not receive run-on surface flow; residuum, short-transport colluvium
Crest	High, narrow area; converging backwearing slopes that form a lowered ridge
Head slope	Convergent overland water flow; thickened colluvium, slope alluvium
Side slope	Parallel overland waterflow; colluvium, slope alluvium, pedisediment, residuum
Nose slope	Divergent overland water flow; colluvium, slope alluvium, pedisediment
Free face	Rock outcrop
Base slope	Concave surface; colluvium, slope alluvium

Figure 2-15



(Modified from Ruhe, 1969)

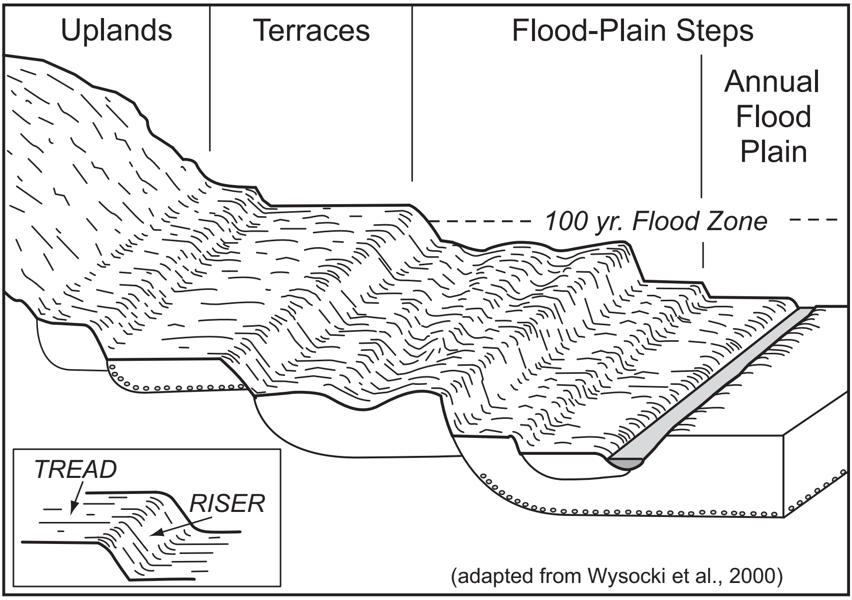
Three-dimensional depiction of geomorphic components of hills.

Table 2-5

Geomorphic Component Terms for Terraces and Stepped Landforms

Geomorphic component term	Typical attributes
Tread	Relatively level, broad surface
Riser	Vertical or steep side slope separating treads

Figure 2-16



(adapted from Wysocki et al., 2000)

Three-dimensional depiction of geomorphic components of terraces and stepped landforms.

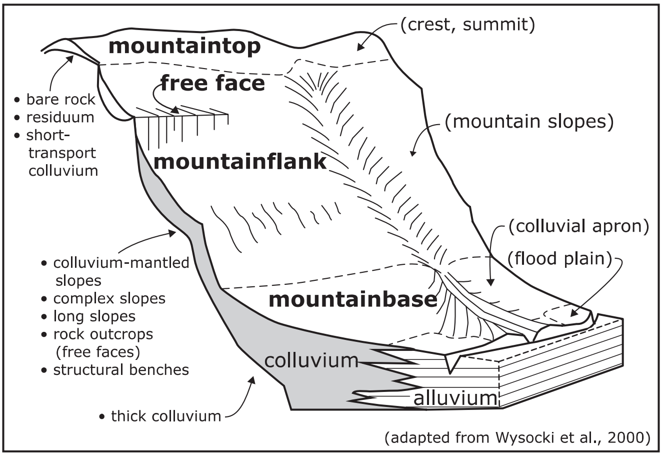
power of the water is reduced as well as its sediment carrying capacity, which determines what sediments are removed and which are left behind. Additionally, there is a general increase, compared to higher gradient systems, in the residence time of water, particularly internal soil water, which alters the biogeochemical dynamics and products. Therefore, new concepts and associated terms were developed for geomorphic components of flat plains. In a similar way, hillslope components were found to be inadequate when applied to high-gradient terrain. Very long and commonly complex slopes and much greater kinetic energy dramatically increase erosion potential and the sediment carrying capacity, can change sediment winnowing effects, can decrease soil water residence time, and can otherwise alter system dynamics and resulting sediments and soils. Therefore, new concepts and associated terms were developed for geomorphic components of mountains. Stream terrace and stepped landforms are also sufficiently unique to warrant separate geomorphic component descriptors.

Table 2-6

Geomorphic Component Terms for Mountains

Geomorphic component term	Typical attributes
Mountaintop	High area (crest, summit); residuum or short transport colluvium, solifluction deposits; generally does not receive run-on surface flow
Mountainflank	Complex slopes, long slopes, substantial gradients, colluvium, mass wasting deposits, talus
Free face	Rock outcrop
Mountainbase	Concave surface; thick colluvium, slope alluvium, mass wasting deposits

Figure 2-17



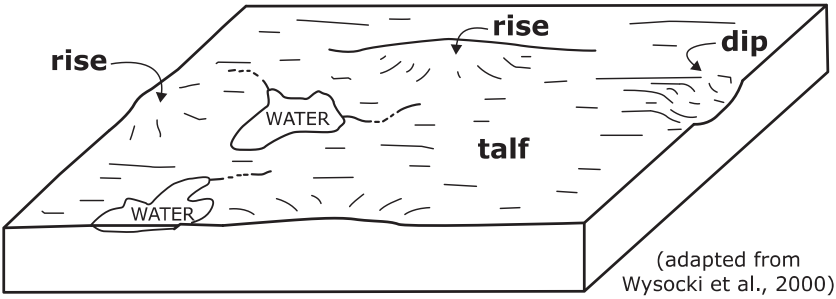
Three-dimensional depiction of geomorphic components of mountains.

Table 2-7

Geomorphic Component Terms for Flat Plains

Geomorphic component term	Typical attributes
Rise	Slightly elevated area (1-3% slopes)
Talf	Very low slope gradients (0-1%); deranged or incipient drainage network; lacustrine deposits, alluvium, till, marine deposits, eolian deposits, and other flat-lying deposits
Dip	Depressions; backswamp deposits, marl, organic deposits, and other deposits in low-lying areas

Figure 2-18



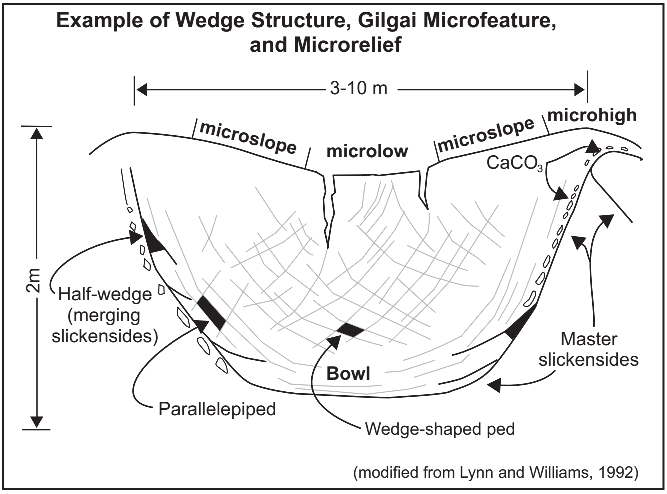
(adapted from Wysocki et al., 2000)

- very low gradients (e.g., slope 0-1%)
- deranged, nonintegrated, or incipient drainage network
- "high areas" are broad and low (e.g., slope 1-3%)
- sediments, commonly lacustrine, alluvial, eolian, or till

Three-dimensional depiction of geomorphic components of flat plains.

Microrelief refers generically to small, relative elevational differences between adjacent areas on the earth surface. In subaerial settings, minor elevational differences can profoundly influence plant growth above ground and, subsequently, water conditions below ground. The lateral scale across which the elevational differences occur is generally on the order of about 3 to 10 meters but can be smaller. A gilgai, which has micro site differences in patterned ground, is an example (fig. 2-19). Terms used to describe microrelief positions are microhigh, microslope, and microlow.

Figure 2-19



Water ponds in the microlows in this area of Vertisols that exhibits gilgai microfeatures (mounds and bowls).

Drainage patterns (also called a *drainage network*) describe the recurring arrangement of interconnected drainage channels across the surface of a land area. They provide substantial insight into the underground, controlling bedrock or regolith (see Way, 1973) as well as the locations where these materials and the overlying soils change. Figure 2-20 presents the more general patterns. Drainage patterns can be best observed and evaluated on aerial photographs, topographic quadrangle maps, or GIS spatial layers that present drainageway patterns in detail.

Figure 2-20

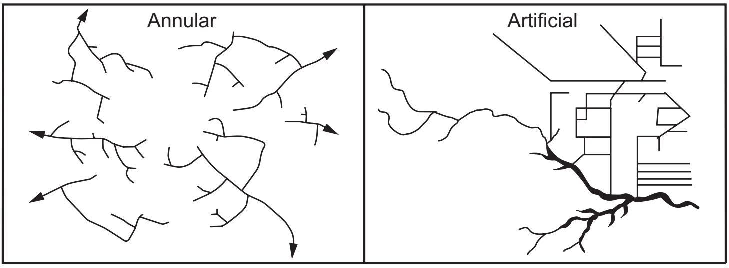


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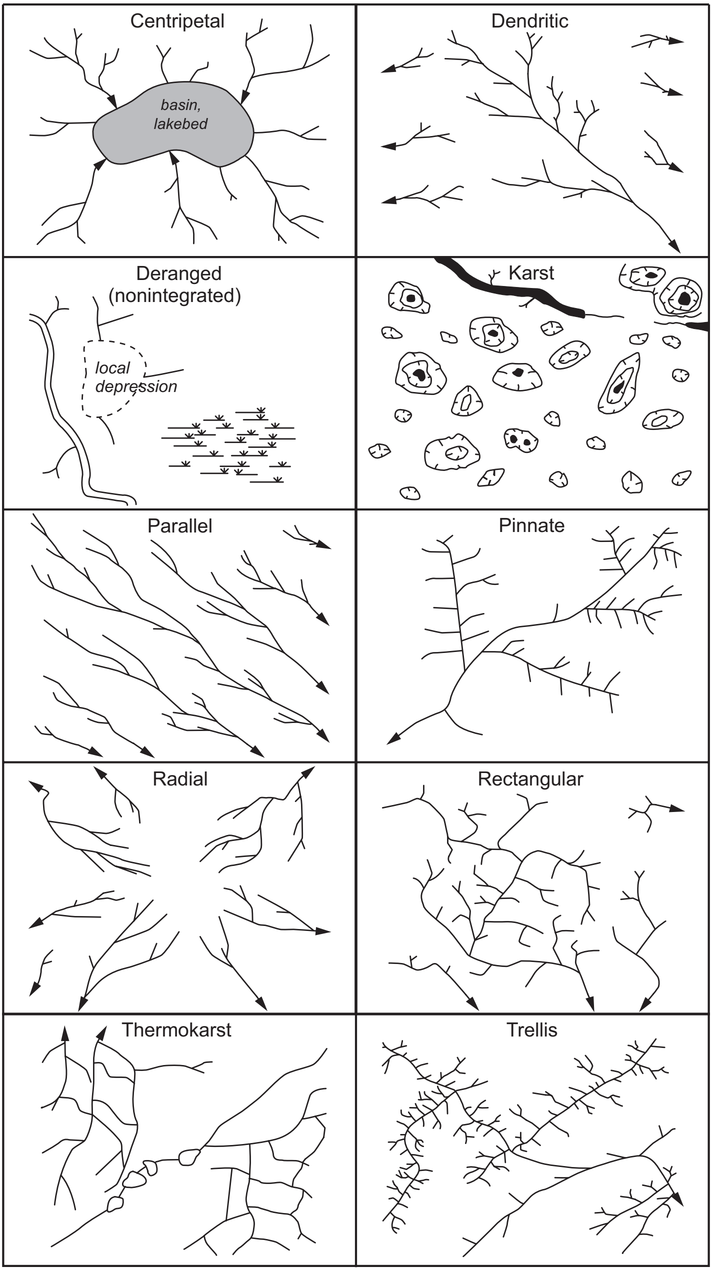
Figure 2-20.—continued



Illustrations and descriptive terms for drainage patterns.

Parent Material

Soil parent material refers to the unconsolidated, organic and mineral materials in which soils form. The unconsolidated material, or regolith, in which a soil develops exerts tremendous influence upon what that soil is and is not and how it behaves. Determining the parent material is therefore important in accurately identifying the composition of the soil. Parent material is more than just soil texture. Other attributes, such as mineralogy, stratigraphy, and the degree of sorting and particle rounding, can substantially affect soil behavior. Eolian sand, such as dunes, can behave hydrologically different than beach sand deposits, even though both are made of sand, due to differences in the internal arrangement and lateral continuity of primary particles. Accurate identification conveys direct and implicit information about the soil itself, the environment in which it formed, and its current environment. Soils provide a record of prevailing and past environments, climates, human activities, and much more.

Importance of Parent Material in Understanding the Soil

Soil formation involves alterations, such as additions, losses, transformations, and translocations and including weathering, of unconsolidated earthy or organic materials (Simonson, 1959). The parent material of a genetic soil horizon cannot be observed in its original state as it has undergone soil formation. Rather, the original state must be inferred from the properties that the horizon has inherited and from other evidence, such as the geomorphic context. In some soils, the parent material has changed little and what it was originally can be deduced with confidence. In other soils, such as some very old, highly altered soils of the Tropics, the specific kind of parent material or its mode of deposition is less clear and more speculative. Regardless, the influence that parent material exerts on the inherent properties and subsequent behavior of soil is substantial. Parent material determines the broad characteristics of what is geochemically present or absent. It directly affects the physical architecture that makes up a soil.

Much of the mineral matter in which soils form is derived from hard bedrock in some way. Glaciers may grind the bedrock into fragments and smaller particles and deposit the unsorted mixture as till. Wind and running water can abrade and entrain small particles that accumulate elsewhere as eolian or fluvial deposits. Bedrock may be weathered and significantly changed chemically and physically but not be moved from its place of origin. Little may be gained from attempting to differentiate between geologic weathering and soil formation because both are weathering processes. It may be possible to infer that a material was weathered before soil formation. The weathering process causes some bedrock constituents to be lost, some to be transformed, and others to be concentrated.

Soil parent material is not always residuum weathered directly from underlying bedrock. The material that developed into the modern soil may not be related to the underlying bedrock at all. In fact, most soils did not form in place but were subject to transport and deposition by wind, water, gravity, or human activities.

Seldom is there absolute certainty that a highly weathered material actually weathered in place. The term "residuum" is used if the properties of the soil indicate that it has been derived from rock similar to that which underlies it and if there is no overt evidence that it has been modified by movement. A decrease in the amount of rock fragments as depth increases, especially over saprolite, indicates that soil material probably has been transported down slope. Stone lines, especially if the stones have a different lithology than the underlying bedrock, are evidence that the soil did not form entirely in residuum. In some soils, transported material overlies residuum and illuvial organic matter and clay are superimposed across the discontinuity between the contrasting materials. A certain degree of landscape stability is inferred for soils that formed in residuum. A lesser degree is inferred for soils that developed in transported material.

Standard terms are used to describe both consolidated and unconsolidated materials beneath the solum that influence the genesis and behavior of the soil. Besides primary observations, the scientist uses his own judgement to infer the origin of the parent material from which the solum developed. Primary observations must precede, and be clearly separated from, inferences.

The lithologic composition, structure, and consistence of the material directly beneath the solum are important. Evidence of stratification of the material should be noted. It includes textural differences, stone lines, and changes in kind and amount of coarse fragments. Commonly, the upper layers of outwash deposits settled out of more slowly moving water and are finer in texture than the lower layers. Windblown material and volcanic ash are laid down at different rates in blankets of varying thickness. Examples of such complexities are nearly endless.

Where alluvium, eolian sands, volcanic ash, or colluvium is rapidly deposited on old soils, buried soils may be well preserved. In other places, the accumulation is so slow that the thicknes of the solum increases only gradually. In these places, the material beneath the solum that was once near the surface may now be buried below the zone of active change.

Where hard rocks or other strongly contrasting materials lie close enough to the surface to affect soil behavior, their properties and the depth to contact need to be measured accurately. The depth of soil over such nonconforming materials is an important criterion for distinguishing different kinds of soil.

General Kinds of Parent Materials

Broad groupings of parent material are discussed in the following paragraphs. Consistent use of terminology to describe parent materials in pedon descriptions and databases enhances the usefulness of the information and allows easier and more reliable comparison of soils that formed in the same kind of parent material. The NCSS has adopted standard terms for many kinds of parent material. These terms are presented in the *Field Book for Describing and Sampling Soils* (Schoeneberger et al., 2012). The terms are fully defined in the *Glossary of Landforms and Geologic Terms* (USDA-NRCS, 2016b).

Material Produced by Weathering of Bedrock

The nature of the original rock affects the residual material produced by weathering. Bedrock undergoes various changes as it weathers, beginning with the progressive removal of readily weatherable minerals, such as plagioclase feldspar and biotite mica. The relative ease of weathering of major minerals was described by Goldich (1938) and refined for some soil clay minerals by McClelland (1950). This weathering sequence indicates which minerals weather most readily and the relative order in which weathering progresses. Evaluating which minerals are present and which have been removed can indicate the degree of weathering that rock has undergone (Coleman and Dethier, 1986).

In-place deposits.—*Saprolite* is soft, friable material produced by bedrock that has been highly weathered in place (*in situ*). The weathering process has removed mineral constituents but left the fabric and structure of the original rock without significant loss in volume (Pavitch, 1986). If the altered material has lost most or all rock fabric and structure and its original volume has been reduced (e.g., by void collapse), the unconsolidated, in-place earthy material is called *residuum*. Such distinctions are useful in recognizing close geochemical and physical relationships to the bedrock of origin. It is assumed that residuum is *in situ* and has not undergone substantive lateral displacement or transport.

Residuum is a major kind of parent material, particularly on older, stable landscapes and in warm and humid climates.

If the soil is derived directly from underlying bedrock and exhibits little or no evidence of lateral transport, the parent material should be identified (e.g., residuum, grus, saprolite, bauxite) and then paired with the kind of bedrock from which it was derived (see "Bedrock" section). The point where rock weathering ends and soil formation begins is not always clear. The processes may be consecutive or overlapping. Quite different soils may form from similar or identical rocks under different weathering conditions. Texture, color, consistence, and other characteristics of the parent material should be included in the description of soils, as well as important remnant bedrock features, such as quartz dikes. Information about the mineralogical composition, consistence, and structure of the parent rock is useful and should also be included.

Transported Material

Most soil parent materials have been moved from their place of origin and deposited elsewhere. The principal subsets of transported materials are typically arranged according to the main geomorphic process responsible for their transport and deposition. In most places, there is sufficient evidence to make a clear determination.

In soil morphology and classification, it is very important to observe and describe the characteristics of the parent material. It is not enough simply to identify the material. Any doubt regarding the identification should be mentioned. For example, it can be difficult to determine if silty deposits are alluvium or loess or to distinguish silty colluvium from silty residuum. It can also be difficult to distinguish certain mud flow deposits from till or to distinguish some sandy tills from sandy outwash. Additional observations across large exposures or at multiple locations help in making such distinctions. These distinctions provide supporting information needed to accurately inventory soils and thereby improve the accurate prediction of soil behavior.

Water-laid or water-transported deposits.—*Alluvium* is a widely occurring parent material. It consists of unconsolidated, sorted, clastic sediment deposited by running water, particularly channel flow. It may occur on actively flooded portions of modern streams. Remnants of old stream terraces may occur in dissected areas far away from, or high above, a present stream or occur as paleoterraces that are unrelated to the modern stream. In larger streams and rivers, a series of alluvial deposits in the form of stream terraces may loosely parallel the modern stream. The youngest deposits occur in the stream; deposits increase in age as they progress to higher levels. In some areas, recent alluvium covers older terraces. For example, younger alluvial fan sediments onlap and bury older fan sediments. Alluvium is also the dominant parent material in large tectonic valleys, such as the bolsons and semi-bolsons of the Basin and Range Physiographic Province in the western United States. On these broad, sloping landscapes, alluvium occurs as thick deposits on active alluvial fans and fan remnants or as broad, relatively level alluvial flats on basin floors. The further down a river system alluvium occurs, the better sorted the sediments tend to be. Larger stream systems commonly have backswamp deposits along low-gradient stream reaches. These lower energy areas are set back from the main channel and are dominated by sediments that are laminated and finer (silts and clays) than alluvium closer to the stream channel. Slope alluvium refers to hillslope sediments transported primarily by slope wash processes (sheet flow) rather than by the channel flow of streams. Crude lateral particle sorting is evident on long slopes, but it is much less evident than the particle sorting in alluvium derived from channel flow.

Lacustrine deposits consist of clastic sediments and chemical precipitates that settled out of bodies of still water, such as ponds and lakes. Deposits associated directly with glaciers and laid down in freshwater lakes (glaciolacustrine deposits) or in oceans (glaciomarine deposits) are included with other glacial deposits. Numerous basins in the western U.S. contained moderate to large pluvial lakes during the Pleistocene epoch. These lakes have either drastically shrunk or disappeared during the warmer and drier climates of the Holocene epoch. The now dry lakebeds are known as playas or salt flats and contain thick lacustrine deposits dominated by silt and clay with interbedded layers of volcanic ash. Some also contain substantial evaporate deposits. Soils in the narrow margins of these barren playas are generally saline, depending on climate and drainage, and are sparsely vegetated with salt-tolerant plants.

Marine deposits settled out of the sea, lagoons, or estuaries and commonly were reworked by currents and tides. Subaqueous soils include sediments that remain under water. Some marine deposits were later exposed either naturally by falling sea levels or following the construction of dikes and drainage canals. Many of the soils of the Atlantic and Gulf of Mexico Coastal Plains in the southeastern U.S. formed in marine sediments deposited during a time of higher sea level. These deposits vary widely in composition. In low-energy settings, such as lagoons, sediments tend to be finer textured and may have intermittent or substantial amounts of organic materials. Higher energy settings can have substantial amounts of sandy material (such as in areas of inlets and barrier islands) or coarser rock fragments (such as in areas of rocky coasts and headlands).

Beach deposits mark the present or former shorelines of lakes or oceans. They consist of low sheets or ridges of sorted material. They are commonly sandy or gravelly (along non-rocky coasts) or cobbly or stony (especially along rocky coasts).

Eolian deposits.—Eolian deposits are very well sorted windblown material. They are broadly divided into groups based on dominant particle size or origin. Examples are aerosols, dust, loess, and eolian sands. All but the finest wind-driven sediments share some depositional traits. "Lateral fining" refers to the progressive reduction in average particle size and deposit thickness as distance increases along the prevailing wind direction and away from the source area. The closer to an eolian sediment source (e.g., a large barren flood plain), the coarser the average particle size and the thicker the eolian deposit. The dominant particle sizes of discrete eolian deposits range from silt and very fine sands (loess) and from fine to medium sands (eolian sands).

Eolian sands are significant due to their physical prominence and the wide range of distinct landforms (especially dune types) they produce. Very fine and fine eolian sands commonly occur as dunes (Bagnold, 1941), and medium sands tend to form sand sheets. Eolian sands are common in, but not limited to, warm, dry regions. They characteristically consist of sands with a high content of quartz and a low content of clay-forming materials. Sand dunes may contain large amounts of calcium carbonate or gypsum, especially in deserts and semi-deserts.

During periods of drought and in deserts, local wind movements may mix and pile up soil materials of different grain sizes, including materials with a high content of clay. Sand-sized aggregates of clay (e.g., parna) can even form dunes (parna dunes). In areas where sand and finer eolian materials are intimately intermingled, the eolian materials may be identified generically as eolian deposits rather than as distinct loess or eolian sands.

Loess deposits are important because their physical and mineralogical properties make them highly suitable to food and fiber production worldwide. Their texture is typically very silty but may range from fine silt to very fine sand. Most loess is pale brown to brown, although gray and red colors are also common. Some colors are inherited from the source material (geogenic colors). Other colors, particularly gray colors, may be caused by post-deposition soil formation, such as redoximorphic alteration resulting in iron reduction. Although thick loess deposits appear to be relatively massive, they have some gross vertical cracking with coarse polygonal structure and can support nearly vertical walls (e.g., roadcut walls) for many years. Silty deposits that formed in other ways have some or all of these characteristics. Windblown silt that has been leached and strongly weathered can be acidic and rich in clay, whereas some young deposits of loess that are mainly silt and very fine sand have a low content of clay.

Other, finer windborne particles also affect soils in unique ways but are not generally recognized as a kind of parent material. Dust is composed of clay or very fine silt-sized particles and can be deposited dry or in precipitation. It can travel great distances from its point of origin, even circle the Earth in the upper atmosphere and be deposited in small increments across the world. After dust settles, the very fine particles are readily mixed into pre-existing soils and may substantially affect soil properties. However, they typically do not form readily identifiable, discrete deposits by themselves. Aerosols are the finest of particulate materials, so small that they can stay suspended in air for extended periods. Wood ash is an example. These particles are typically too fine and too diffuse to accumulate as separate deposits. Consequently, they are not identified as discrete parent materials in soil survey. Nonetheless, they can contribute meaningful amounts of carbon ash, pollen, quartz, or other materials to soils. They typically settle out as raindrop nuclei and infiltrate soil in suspension or settle in water bodies. Other soil constituents accompany precipitation, such as atmospheric elements in solution (fixed nitrogen, sulfur, calcium, magnesium, sodium, potassium, etc.) but are not included within the concept of parent materials.

A conventional practice in considering geomorphic processes is to include volcanic eolian deposits, such as ash and pumice, with other volcanic materials (see “Volcanic Deposits” below) because their origin, including mineralogical composition and depositional dynamics, is closely associated with volcanism.

Glacial and periglacial deposits.—Glacial and periglacial deposits are derived from material moved and deposited by glacial processes or associated with cold climates. However, the two types have two distinct geomorphic process systems. Their processes and sediments are commonly associated because they share very cold climatic settings and driving forces. They are considered together here for convenience. Glacial refers to materials that have been directly created, moved, and deposited by glacial ice (i.e., drift and till). A conventional practice in considering geomorphic processes is to include glaciofluvial, outwash, and glaciolacustrine deposits among other glacial materials because their origins, including depositional dynamics, resulting stratigraphy, and mineralogical composition, are closely associated.

Drift is a general, inclusive term for all material picked up, mixed, disintegrated, transported, and deposited by glacial ice or glacial meltwaters. The term is so generic that it is principally used for very coarse scales that prohibit details. In many places, drift is mantled by loess. Thick mantles of loess are typically easily recognized, but very thin mantles may be so mixed by soil-building processes that they can scarcely be differentiated from the underlying drift.

Till is a type of drift that was deposited directly by ice and had little or no transportation by water. It is generally an unstratified and heterogeneous (i.e., unsorted) mixture of clay, silt, sand, gravel, and boulders. Some of the ice-entrained mixture settled out as the ice melted and was subject to very little washing or reworking by water (ablation till), and some was overridden by the glacier and became compacted (lodgement till). Till occurs in various glacial landforms. Ground moraines and recessional moraines are examples. In many places, it is important to differentiate tills of several glaciations. Commonly, the tills underlie one another and may be separated by other deposits or old, weathered surfaces. In many cases, till was later eroded by the wave action in glacial lakes. The upper part of such wave-cut till may have a high percentage of rock fragments.

Till ranges widely in texture, chemical composition, and degree of weathering. It is principally affected by the composition of the bedrock it has overridden and whose materials it has entrained. Tills of the mid-continental U.S. are underlain by sedimentary rocks, such as limestone and shale, and typified by heavy textures (clay, clay loams). In contrast, tills of northern Minnesota, New England, and Canada underlain by crystalline bedrock, such as granite, are typified by coarser textures (gravelly sandy loam). Much till is calcareous, but a significant amount is noncalcareous because no carbonate rocks contributed to the till or because subsequent leaching and chemical weathering have removed the carbonates. The two most widely occurring and operationally important types of till are ablation till and lodgement till. Ablation till is characterized by a comparatively low bulk density (e.g., 1.4 g/cm^3) and occurs at the top of till deposits. Lodgement till formed beneath a glacier and was over-compacted. As a result, it has a very high bulk density (e.g., 1.8 g/cm^3) that substantially restricts internal water flow and makes excavation difficult. Some tills are identified by position of formation relative to the glacial ice. Supraglacial till formed by the sediments on top of or entrained with the ice that settled out as the ice melted (ablation till or melt-out till) or moved as localized mud flows (flow till). Subglacial till, such as lodgement till, formed beneath glacial ice.

Glaciofluvial deposits are materials moved by glaciers and subsequently carried, sorted, and deposited by meltwaters flowing from the ice. *Outwash* is a parent material term for the detritus (chiefly sand and gravel) removed or “washed out” from a glacier by meltwater streams and deposited beyond the ice front or end moraine. The coarsest material was deposited nearer the ice. This outwash commonly forms on plains, valley trains, outwash terraces, or deltas in drainageways or in relict glacial lakes. Some outwash terraces may extend far beyond the farthest advance of the ice. Near moraines or in disintegration moraine landscapes, sorted glaciofluvial material may form kames, eskers, and crevasse fills.

Glacial beach deposits consist of rock fragments and sand. They mark the locations of relict shorelines (i.e., strandlines) of former glacial lakes. Depending on the character of the original drift, beach deposits may be sandy, gravelly, cobbly, or stony.

Glaciolacustrine deposits are also derived from glaciers but were reworked and laid down in glacial lakes. These deposits range from fine clay to sand. Many of them are stratified or varved. A *varve* is the pair of deposition laminae for a calendar year. The finer portion reflects lower energy deposition during the cold season, and the slightly coarser portion reflects higher energy deposition during the warmer season when runoff is greater and wave action occurs.

In many places, it is difficult to distinguish between the different kinds of glacial sediments. For example, pitted outwash plains can be difficult to distinguish from sandy till in recessional moraines and wave-cut till can be difficult to distinguish from lacustrine material. Typically, even the most subtle differences can be identified from multiple, well planned field observations. This information is used to accurately determine the geomorphic setting and its associated sediments. Careful observations and descriptions of parent material, stratification, coarse fragment distribution, and the surface forms in which they occur provide hard evidence needed for correct conclusions. However, some situations are not fully understood at present because of their complexity or incomplete scientific knowledge.

Periglacial deposits have several major types. Cryoturbates are deposits of sediments that have been mixed or preferentially sorted by seasonal frost heave, partial melting and refreezing of permafrost, or other non-glacial ice displacement processes. These processes can organize sediments in several ways. Internally, the materials typically exhibit convolutions or low-grade internal sorting, unlike the more horizontal layering typical of mineral soils in warmer climates. Surficial sorting, particularly of coarse fragments, can take the form of polygons or stripes or other patterned ground. Solifluction deposits consist of heterogeneous mixtures of textures, including rock fragments. The orientation of the rock fragments indicates the slow downslope movement that resulted in surficial lobes, sheets, and terraces. Solifluction deposits form in response to seasonal or partial thawing of the near surface “active zone.”

Periglacial parent materials can have wide aerial extent. Active or recent periglacial deposits occur most extensively at high latitudes or at high elevations outside of, or otherwise unaffected by, glacial ice. Relict solifluction deposits also widely occur in the form of relict patterned ground in association with former continental glaciated areas in mid latitudes.

Mass wasting (mass movement) deposits.—Some materials are transported primarily or completely by gravity. Transport can occur extremely quickly or gradually. *Landslide deposits* is a generic term that includes all forms of landslide materials. These deposits can be more explicitly identified based on the main mode of movement (table 2-8).

Table 2-8

Types of Landslide Deposits

Movement types	Deposit attributes
Fall deposits	Free fall, bouncing or rolling
Topple deposits	Forward rotation over a basal pivot point
Slide deposits: Rotational landslide	Backward rotation around a pivot point above the ground surface
Slide deposits: Translational slide	Mass lateral displacement along a planar slip face
Spread deposits	Layers plastically extruded by liquefaction
Flow deposits	Wet or dry mass flow that behaves as a viscous liquid

Each of these movement types can be further subdivided to indicate the dominant kind of material moved: rock (consolidated bedrock masses), debris (unconsolidated material rich in rock fragments), or earth (dominantly fine-earth material). (See Mass Movement (Wasting) Types table in Schoeneberger et al., 2012.) These terms are useful in specifying different levels of detail needed to identify areas according to their associated deposits. They are also used to convey the composition of the present materials, which impacts land management decisions.

Other kinds of gravity-related deposits are widely recognized. *Colluvium* is poorly sorted slope sediments that have been transported and accumulated along or at the base of slopes, in depressions, or along small streams primarily due to gravity, soil creep, and slope wash processes. Accumulations of rock fragments at the base of rock outcrops are called *talus*. Rock fragments in colluvium are typically very angular to sub-rounded due to relatively short transport distances and the limited abrasion associated with the process. In contrast, rock fragments in alluvium and glacial outwash are rounded to well rounded and waterworn.

Organic deposits.—Organic deposits are material dominated by carbon-rich plant or organism detritus. The organic material accumulates more rapidly than it decomposes. This unconsolidated material is commonly associated with, but not restricted to, wet soil or subaqueous conditions. Organic deposits can persist in extremely dry settings or under other conditions that reduce or eliminate microbial decomposition, such as low oxygen or low pH (acidic). These latter conditions can produce various types of organic accumulations that may become the soil parent material generically called "organic materials." Organic deposits can be further defined according to the dominant plant material present, such as woody, herbaceous, grassy, or mossy. Different terms are used to modify an associated soil texture (e.g., mucky, peaty). Terms used *in lieu* of texture for organic materials include muck, peat, and highly decomposed organic materials (see chapter 3).

Some organic materials occur as alternating layers of different kinds that reflect the dominant vegetative cover at the time of deposition. Others are combinations of peat and mineral materials. In some places, organic materials cap, are intimately mixed with, or are discretely interlayered with volcanic ash, marl, alluvium, or eolian sands. Descriptions of organic material (see chapter 3) should include labels (e.g., woody organic materials) or notations identifying the origin and dominant botanical composition, to the extent that they can be reasonably inferred.

Volcanic deposits.—Volcanic eolian deposits, such as ash and pumice, are treated separately from other eolian parent materials because of their unique mineralogy and depositional dynamics. Tephra, volcanic ash, pumice, and cinders are unconsolidated igneous sediments that were ejected during volcanic eruptions and moved from their place of origin. Most have been reworked by wind and, in some places, by water. *Tephra* is a broad, generic term referring to any form of volcanic ejecta. Various subdivisions are recognized and should be used when possible. *Ash* is volcanic ejecta smaller than 2 mm. It can be subdivided into fine ash (< 0.06 mm) and coarse ash (> 0.06 and < 2 mm). *Pumice* is volcanic ejecta larger than ash (> 2 mm) that has a low specific gravity (< 1.0). *Cinders* are volcanic ejecta larger (> 2 mm and < 64 mm) than ash and heavier (specific gravity > 1.0 and < 2.0) than pumice. (See Pyroclastic Terms table in Schoeneberger et al., 2012.)

Anthropogenic deposits.—Human-transported material is a general term for solid phase organic or mineral material that can function as soil or soil-like material. It has been mixed and moved from a source area to a new location by purposeful human activity, usually with the aid of machinery or hand tools. There has been little or no subsequent reworking by wind, gravity, water, or ice. Human-transported materials are most commonly associated with building sites, mining or dredging operations, landfills, or other activities that result in the formation of a constructional anthropogenic landform. Anthropogenic material differs from natural deposits in that its internal composition and stratigraphic arrangements depend upon the emplacement methods, tools, and intentions of people. It is generally more variable and less predictable in its content and configuration than material emplaced by natural processes. Nonetheless, it can be described and broadly quantified in ways similar to how natural materials are evaluated.

In database management, it is helpful of have an alphabetical master list of the many kinds of parent materials. The diverse kinds of parent materials can also be constructively arrayed within subsets based upon the dominant geomorphic processes that erode, transport, or deposit them (see "Parent Material" section in Schoeneberger et al., 2012). Table 2-9 lists parent material groups based on geomorphic process or setting.

Table 2-9

General Groups of Parent Materials Based on Geomorphic Process or Setting

General groups	Specific examples
Anthropogenic deposits	Dredge spoil, mine spoil, earthy fill
Eolian deposits (nonvolcanic)	Eolian sands, loess
Glacial and periglacial deposits	Till, solifluction deposit
In-place deposits (nontransported)	Residuum, saprolite
Mass wasting deposits	Mudflow deposit, talus
Miscellaneous deposits	Diamicton, gypsite
Organic deposits	Diatomaceous earth, grassy organic materials
Volcanic deposits	Andesitic ash, pumice
Water-laid or water-transported deposits	Alluvium, lacustrine deposit

These subsets compliment and loosely parallel the geomorphic environment categories presented in the Geomorphic Description System used by the NCSS (Schoeneberger et al., 2012). Soil parent materials should generally relect the dominant geomorphic environment and vice versa.

Multiple Parent Materials

Soil is commonly composed of layers of several different types of parent materials (e.g., colluvium over residuum) that are identifiable in the soil's stratigraphy. For example, till is covered by a mantle of loess in many places. Thick mantles of loess are easily recognized, but very thin (e.g.,< 25 cm) mantles may be so altered by soil-building processes, such as pedoturbation, that they can scarcely be differentiated from the underlying till. The contact between substantially different (contrasting) parent materials in a soil is called a lithologic discontinuity. It should be documented using horizon description nomenclature (see chapter 3) and other descriptive conventions.

Unconsolidated contrasting soil material may differ in pore-size distribution, particle-size distribution, mineralogy, bulk density, or other properties. Some of the differences may not be readily observable in the field. Some deposits are clearly stratified, such as some lake sediments and glacial outwash, and the discontinuities are sharply defined.

The primary deposition differences of multiple, contrasting parent materials can be confused with the effects of soil formation. Silt content may decrease regularly with increasing depth in soils presumed to have formed in till. The higher silt content in the upper part of these soils can be explained by factors other than soil formation. In some of these soils, small amounts of eolian material may have been deposited on the surface over the centuries and mixed with the underlying till by insects and rodents or freeze-thaw action. In others, the silt distribution may reflect water sorting.

Inferences about contrasting properties inherited from differing layers of geologic material may be noted when the soil is described. Generally, each identifiable layer that differs clearly in properties from adjacent layers is recognized as a horizon or subhorizon. Whether it is recognized as a discontinuity or not depends upon its degree of contrast with overlying and underlying layers and its thickness.

A pragmatic balance is needed between identifying the dominant parent material layer(s) in a soil and not becoming overwhelmed by excessive detail. While there are no rigid criteria, such as a thickness minimum, it is particularly important to identify layers that are physically contrasting enough and thick enough to substantively affect internal water flow. There are several widely recognized exceptions for which numerous sediment layers are not comprehensively described. For deposits that are intrinsically highly stratified, whose lateral continuity is intermittent, it is impractical to identify or sample every thin layer (lamina). For finely laminated alluvium or tephra deposits, only the larger, aggregate layers are identified and sampled as composites (bulked). Minor layers (laminae) within larger layers are noted but typically are not comprehensively documented nor sampled individually.

Bedrock

The term "bedrock" as used in soil survey refers to continuous, coherent (consolidated) rock. It can be a physical barrier within the solum that limits rooting depth or the immediate parent material source for residual soils. Bedrock helps to determine local topography and the soils that form across it. It can also indirectly impact soils. If fairly close to the base of the solum, bedrock can affect the presence or absence of ground water and preferential flow direction, depending upon its porosity. It can be a determinant factor in slope stability (tendency for landslides) or impact excavation, such as soil suitability for basements and road construction. Identifying the bedrock, whether its influence is direct or indirect, is essential in understanding the intrinsic chemical and physical behavior of both the rock material itself and its soil or regolith derivatives. Bedrock also has a major impact on soil geography and the accurate prediction of it. Boundaries between types of bedrock commonly, but not always, coincide with changes in overlying soil types. Therefore, accurate recognition and documentation of bedrock is generally essential. In some natural settings, the documentation of bedrock may be problematic, impractical, or unnecessary. Bedrock is not recorded if it does not exert substantial influence on the soil. An example is bedrock that is deeply buried by regolith, such as till, basin fills, and coastal or lacustrine sediments.

Geological materials need to be defined in accordance with the accepted standards and nomenclature of geology. The accepted, authoritative names of the geological formations are recorded in soil descriptions. As soil research progresses, there is an increasing number of correlations between particular geological formations and the mineral and nutrient content of parent materials and soils. Examples include: (1) certain terrace materials and deposits of volcanic ash that are different in age or source, but otherwise indistinguishable, may vary widely in content of cobalt; (2) the phosphorus content of otherwise similar soils may vary widely due to similar limestones that can be distinguished in the field only by specific fossils.

Igneous rocks formed by the solidification of magma that originated within Earth's upper mantle. There are two main types based on their mode of formation—intrusive and extrusive. Intrusive (syn., plutonic) types form at considerable depth in the Earth's crust and possess a coarse grain texture due to the slow cooling of magma. Examples of intrusive igneous rocks that weather to soil parent material are granite, diorite, and gabbro. Extrusive (syn., volcanic) types form on the Earth's surface or at very shallow depth and possess a fine grain texture due to the rapid cooling of magma. Examples of common extrusive igneous rocks are rhyolite, andesite, and basalt.

Sedimentary rocks formed from sediments laid down in previous geological ages. The principal broad groups of sedimentary rocks are clastic, chemical, and organic. Examples of rock lithologies in the clastic group are shale, sandstone, and conglomerate; examples of those in the chemical group are limestone, gypsum rock, and travertine; and examples of those in the organic group are coal and diatomite. There are many varieties of these lithologies. For example, chalk is a soft variety of limestone. Many lithologies are intermediate between the broad groups. Examples are calcareous sandstone and arenaceous limestone.

Metamorphic rocks resulted from profound alteration of igneous and sedimentary rocks by heat and pressure. General classes of metamorphic rocks important as parent material are gneiss, schist, slate, marble, quartzite, and phyllite.

Kinds of Bedrock

Kind is the most important bedrock feature to describe. It indicates the general composition of the rock and how the rock and its weathering products are likely to behave. Soil survey follows standard conventions for rock type compositions and names (Neuendorf et al., 2005). There is a large number of officially recognized rock types. They are very detailed and can be functionally cumbersome for soil survey. Subsequently, soil survey tends to focus on broader categories and common rock types, particularly those found in the near surface environment. More obscure or minor rock types can be recognized if they have important economic or environmental impact. Some databases maintain long alphabetical master lists of bedrock. A helpful way to arrange the large number and variety of bedrock kinds is to separate them into widely recognized subsets, such as igneous, metamorphic, and sedimentary (Schoeneberger et al., 2012; USDA-NRCS, 2016b). In addition to bedrock kind, descriptions of bedrock should include information about the spacing of fractures, degree of weathering, and depth to contact (if within or near the solum).

The general groups of bedrock types described earlier can be subdivided or rearranged slightly to provide groups of bedrock types commonly pertinent to soils:

Igneous-intrusive.—Examples are anorthrosite, diabase, and granite.
Igneous-extrusive.—Examples are a'a lava, andesite, and basalt.
Igneous-pyroclastic.—Examples are pyroclastic flow, tuff, and volcanic breccia.
Metamorphic.—Examples are amphibolite, gneiss, and schist.
Sedimentary-clastics.—Examples are arenite, argillite, and mudstone.
Interbedded.—Examples are limestone-sandstone, sandstone-shale, and shale-siltstone.
Evaporites, organics, and precipitates.—Examples are tufa, coal, and limestone.

Depth to Bedrock

Depth to bedrock is a crucial feature because of its impact on plant growth, internal water dynamics and direction, and land management. This is particularly true for agricultural soils if hard bedrock is within 2 meters of the surface. Bedrock can limit rooting depth, reduce the potential soil water supply, affect internal water flow, and impact various mechanical activities, such as deep ripping, foundation excavation, fence post placement, and suitability for basements. The depth from the ground surface to the contact with bedrock should be recorded.

Fracture Interval

Most bedrock contains a natural joint or crack network that functions as by-pass flow routes for internal water. These fractures can vary substantially in the amount of water they are able to transmit and can potentially affect pond integrity, internal pollutant movement, and water well yields. If observable, the average horizontal spacing between vertical rock joints in the bedrock layer is described.

Weathering

Not all bedrock is chemically and/or physically altered from its pristine state to the same extent. Weathering generally increases porosity and the water-holding capacity and reduces bulk density and coherency. A weathering class (e.g., slight, moderate, strong) can be assigned to record the bedrock's subjective extent of weathering as compared to its presumed unweathered state.

Lithostratigraphic Units

Lithostratigraphic units are mappable rock or sediment bodies. In geochronology, younger units overly older units (law of superposition). Regolith units, both unconsolidated material and bedrock units, are identified and named according to standard conventions of the International Stratigraphic Code (e.g., North American Commission on Stratigraphic Nomenclature, 2005). Table 2-10 lists these units in descending rank. This naming system provides a standard, shorthand method of identifying and concisely communicating information on strata and rock type. It aids recognition of differences in geology and the soils developed in or on them. Some soils, particularly residual soils, can be linked to specific bedrock units. Other soils, such as loess, can occur across multiple bedrock units if their lithostratigraphic unit is not bedrock constrained. If possible, the hierarchical lithostratigraphic units at a site should be recorded (Schoeneberger et al., 2012).

Table 2-10

Lithostratigraphic Units and Their Hierarchical Rank and Definition

- *Supergroup.*—The broadest lithostratigraphic unit. A supergroup is an assemblage of related, superposed groups, or groups and formations. It is most useful for regional synthesis.
    - *Group.*—The second ranking lithostratigraphic unit. A group is a named assemblage of superposed formations and may include unnamed formations. It is useful for small-scale (broad) mapping and regional stratigraphic analysis.
        - *Formation (or Geologic Formation).*—The basic lithostratigraphic unit used to describe, delimit, and interpret sedimentary, extrusive igneous, metavolcanic, and metasedimentary rock bodies (excluding metamorphic and intrusive igneous rocks). It is based on lithic characteristics and stratigraphic position. A formation is commonly, but not necessarily, tabular and stratified and is of sufficient extent to be mappable at the Earth's surface or traceable in the subsurface at conventional mapping scales.
            - *Member.*—The formal lithostratigraphic unit next in rank below a formation and always part of a formation. A formation need not be divided selectively or entirely into members. A member may extend laterally from one formation to another.

- *Lens (or Lentil).*—A specific type of member. A lens is a geographically restricted member that terminates on all sides within a formation.
- *Tongue.*—A specific type of member. A tongue is a wedge-shaped member that extends beyond the main formation boundary or that wedges or pinches out within another formation.
  - *Bed.*—The smallest lithostratigraphic unit of sedimentary rock. A bed is a subdivision of a member based upon distinctive characteristics or economic value (e.g., coal member). Members need not be divided selectively or entirely into beds.
  - *Flow.*—The smallest lithostratigraphic unit of volcanic rock. A flow is a discrete, extrusive, volcanic body distinguishable by texture, composition, superposition, and other criteria.

Erosion

Erosion is the detachment and movement of soil material. The process may be natural or accelerated by human activity. Depending on the local landscape and weather conditions, erosion can range from very slow to very rapid. Loss of the soil surface layer has a direct detrimental impact on site productivity and on off-site sedimentation and nutrient inputs. It is especially important to evaluate for environmental and agronomic purposes. The dominant kind and degree (relative magnitude) of accelerated erosion at the site should be estimated.

Natural Erosion

Naturally occurring erosion sculptured landforms on the uplands and built landforms on the lowlands. Its rate and distribution in time control the age of land surfaces and many of the internal properties of the soils on them. The formation of the Channel Scablands in the State of Washington is an example of extremely rapid natural, or geologic, erosion. The broad, nearly level interstream divides on the Coastal Plain of the southeastern United States are examples of areas with very slow or no natural erosion.

Landscapes and their soils are evaluated from the perspective of their natural erosional history. Evidence that material has been moved and redeposited, including buried soils, stone lines, and deposits of windblown material, is helpful in understanding natural erosion history. Thick weathered zones that developed under earlier climatic conditions may have been exposed and become the material in which new soils formed. In landscapes of the most recently glaciated areas, the consequences of natural erosion, or lack of it, are less obvious than where the surface and the landscape are early Pleistocene or even Tertiary in age. However, even on the landscapes of the most recent glaciation, postglacial natural erosion may have redistributed soil materials on the local landscape. Natural erosion is an important process that affects soil formation and, like human-induced erosion, can remove all or part of soils formed in the natural landscape.

Accelerated Erosion

Accelerated erosion is largely the consequence of human activities, primarily those that result in a loss of soil cover, such as tillage, grazing, and cutting of timber. Kinds are listed in table 2-11 and discussed below.

Table 2-11

Kinds of Accelerated Erosion

Erosion kind	Criteria
Wind	Deflation by wind
Water:	Removal by running water
Sheet	Relatively uniform soil loss; no channels
Rill	Small channels (can be obliterated by conventional tillage)
Gully	Big channels (cannot be obliterated by conventional tillage)
Tunnel	Subsurface voids within soil that are enlarged by running water (i.e., piping)

The rate of erosion can be increased by events besides human activities. For example, fire that destroys vegetation can trigger erosion. Spectacular episodes of erosion, such as the soil blowing on the Great Plains of the central United States in the 1930s, have not all been due to human activities; frequent dust storms were recorded on the Great Plains before the region became a grain-producing area.

Accelerated erosion may not be easy to distinguish from natural erosion on some soils. A distinction can be made by studying and understanding the sequence of sediments and surfaces on the local landscape as well as by studying soil properties. For example, in some areas of the eastern United States, native forests were cut and burned to create cropland. In some places where the soils were particularly susceptible, this resulted in extensive soil erosion. The sediments from the uplands can be observed on adjacent flood plains as a sequence of layers that, in some places, are up to a few meters thick over a buried soil. The contact between the original soil surface and new sediments commonly is evidenced by numerous pieces of charcoal above the contact, which presumably originated from the burning of timber.

Wind Erosion

The term "wind erosion," as used in this manual, in soil science generally, and by many geologists, indicates the detachment, transportation, and deposition of soil particles by wind, not the sculpture of rocks by windblown particles. Wind erosion in regions of low rainfall can be widespread, especially during periods of drought. Unlike water erosion, wind erosion is generally not related to slope gradient. The hazard of wind erosion is increased by removing or reducing the amount of vegetation. When winds are strong, coarser particles are rolled, or swept along, on or near the soil surface and finer particles are forced into the air. The particles are deposited in places sheltered from the wind. When wind erosion is severe, the sand particles may drift back and forth locally with changes in wind direction while silt and clay are carried away. Small areas in which the surface layer has blown away may be associated with areas of deposition in such an intricate pattern that the two cannot be identified separately on soil maps.

Water Erosion

Water erosion results from the removal of soil material by flowing water, including the detachment of soil material by the impact of raindrops. The soil material is suspended in runoff water and carried away. Some sediment may be carried just a few meters before being deposited, while other sediment may be completely removed from the site. Four kinds of accelerated water erosion are commonly recognized: sheet, rill, gully, and tunnel (piping).

Sheet erosion is the more or less uniform removal of soil from an area without the development of conspicuous water channels. The channels are tiny or tortuous, exceedingly numerous, and unstable. They enlarge and straighten as the volume of runoff increases. Sheet erosion is less apparent, particularly in its early stages, than other types of erosion. It can be a problem for soils that have a slope gradient of only 1 or 2 percent; however, it is generally more of an issue as slope gradient increases.

Rill erosion is the removal of soil as concentrated runoff cuts many small, but conspicuous, channels. It is intermediate in degree between sheet and gully erosion. The channels are shallow enough that they are easily obliterated by tillage. After an eroded field has been cultivated, determining whether soil losses resulted from sheet or rill erosion is generally impossible.

Gully erosion is the removal of soil by water along the line of flow. Gullies form in exposed natural drainageways, in plow furrows, in animal trails, in vehicle ruts, between rows of crop plants, and below broken human-made terraces. Unlike rills, they cannot be obliterated by ordinary tillage. Deep gullies cannot be crossed with common types of farm equipment.

Gullies and gully patterns vary widely. V-shaped gullies form in material that is equally or increasingly resistant to erosion with increasing depth. U-shaped gullies form in material that is equally or decreasingly resistant to erosion with depth. As the substratum is washed away, the overlying material loses its support, falls into the gully, and is also washed away. Most U-shaped gullies become modified toward a V shape once the channel stabilizes and the banks begin to crumble and slump. The maximum depth to which gullies are cut is governed by resistant layers in the soil, by bedrock, or by the local base level. Many gullies develop headward, i.e., they extend up the slope as the gully deepens in the lower part.

Tunnel erosion may occur in soils with subsurface horizons or layers that are more subject to entrainment than the surface horizon or layer. Through ponded infiltration, the free water enters into the soil's surface-connected macropores. Desiccation cracks and rodent burrows are examples of macropores that may initiate the process. The soil material incorporated into the moving water travels downward within the soil profile, and if there is an outlet, may move out of it completely. As a result, tunnels (also referred to as pipes) form, enlarge, and coalesce. The portion of the tunnel near the inlet may enlarge disproportionately to form a funnel-shaped feature, commonly referred to as a "jug." This phenomenon is called "piping" or "jugging" and occurs especially in areas with appreciable amounts of exchangeable sodium.

Sediment carried by water typically is deposited wherever the water's velocity slows, such as at the mouth of gullies, at the base of slopes, along streambanks, on alluvial plains, in reservoirs, and at the mouth of streams. Water moving rapidly can deposit stones. As it slows, it deposits cobbles, followed by gravel, sand, and finally silt and clay. The slope length for sediment transport is the distance from the highest point on the slope where runoff may start to where the sediment in the runoff would be deposited.

Estimating the Degree of Erosion

Soil examinations can estimate the degree to which accelerated erosion has modified the soil. However, estimating the amount of surface soil that is no longer present can be very difficult. This is generally most feasible if sufficient areas of the soil are known to be little affected by past accelerated erosion and can be used for comparison studies. The recognition of eroded and uneroded phases of a soil is useful if at least some soil properties making up the eroded phase are different enough from those of the uneroded phase to impact the soil's use and management. The eroded soil is identified and classified on the basis of the properties of the soil that remains and not on what was presumed to have been present in the past. In some cases, the eroded soil may classify differently from the uneroded soil. An estimate of the soil lost is described. Eroded soils are defined so that the boundaries on the soil maps separate soil areas with different use suitabilities and different management needs.

The depth to a reference horizon or soil characteristic in areas under a use that has minimized erosion are compared to the same properties in areas under uses that have accelerated erosion. For example, a soil that supports native grass or large trees with no evidence of cultivation could be compared with the same or similar soil that has been cleared and cultivated for a relatively long time. The depth to reference layers is measured from the top of the mineral soil because cultivation destroys organic horizons at the surface.

The depth to a reference layer must be interpreted in terms of recent soil use or history. The upper parts of many forested soils have roots that make up as much as one-half of the soil volume. When these roots decay, the soil settles. Removal of rock fragments can also lower the surface. Cultivation may cause differences in thickness of layers. The thickness of surficial zones that have been bulked by tillage should be adjusted downward to what they would be under natural conditions.

The thickness of a plowed layer cannot be used as a standard for either losses or additions of material because, as a soil erodes, the plow cuts progressively deeper. Nor can the thickness of the uncultivated and uneroded A horizon be used as a standard for all cultivated soils, unless the A horizon is much thicker than the plow layer. If the horizon immediately below the plowed layer of an uneroded soil is distinctly higher in clay than the A horizon, the plow layer becomes progressively more clayey under continued cultivation as erosion progresses. In this case, the texture of the plow layer can be a criterion of erosion. Comparisons must be made on comparable slopes. Near the upper limit of a soil's range of slope gradient, horizons may normally be thinner than near the lower limit.

Roadsides, cemeteries, fence rows, and similar uncultivated areas that make up a small part of the landscape or were subject to unusual cultural histories must be used cautiously for setting standards. In these areas, the reference standards for surface layer thickness are generally set too high. In naturally treeless areas or in areas cleared of trees, dust may collect in fence rows, along roadsides, and in other small uncultivated areas that are covered with grass or other stabilizing plants. This accumulated dust may cause the surface horizon to become several centimeters thicker in a short time.

For soils having clearly defined horizons, differences due to erosion can be accurately determined by comparison to undisturbed or uncultivated sites. Guidelines for estimating erosion for soils with a thin A horizon and little or no other horizon are more difficult to establish. After the thin surface layer is gone or has been mixed with underlying material, few clues remain for estimating the degree of erosion. One must rely on the physical conditions of the material in the plowed layer, the appearance and amount of rock fragments on the surface, the number and shape of gullies, and similar evidence. For many soils having almost no horizon expression, attempting to estimate the degree of erosion serves no useful purpose.

Precise estimates of the amount of soil lost from a site based on comparison studies with a similar uneroded site are complicated by several factors. The goal is to establish map unit concepts that reflect the relative degrees of soil loss between eroded phases of a soil and that result in some significant differences in the use and management of the soils based on their current properties.

Degree Classes for Accelerated Erosion

The degree classes for accelerated erosion discussed below and listed in table 2-12 apply to both water and wind erosion. They are not applicable to landslip or tunnel erosion. The classes pertain to the proportion of upper horizons that has been removed. These horizons may range widely in thickness; therefore, the absolute amount of erosion is not specified.

Table 2-12

Degree Classes for Accelerated Soil Erosion

Degree class	Criteria: Estimated % loss of the original combined A + E horizons, or the estimated loss of the upper 20 cm (if original, combined A + E horizons are < 20 cm thick)
None	0 %
1	> 0 to 25 %
2	25 to 75 %
3	75 to 100 %
4	> 75 % and total removal of the A horizon

Class 1.—This class consists of soils that have lost some, but on average less than 25 percent, of the original A and/or E horizons or of the uppermost 20 cm if the original A and/or E horizons were less than 20 cm thick. Throughout most of the area, the thickness of the surface layer is within the normal range of variability of the uneroded soil. Less than 20 percent may consist of scattered small areas with a significantly modified surface layer.

Evidence for class 1 erosion includes: (1) a few rills, (2) accumulation of sediment at the base of slopes or in depressions, (3) scattered small areas where the plow layer contains material from below, and (4) evidence of the formation of widely spaced, deep rills or shallow gullies without consistently measurable reduction in thickness or other change in soil properties between the rills or gullies.

Class 2.—This class consists of soils that have lost, on average, 25 to 75 percent of the original A and/or E horizons or of the uppermost 20 cm if the original A and/or E horizons were less than 20 cm thick. Throughout most cultivated areas of class 2 erosion, the surface layer consists of a mixture of the original A and/or E horizons and material from below. Some areas may have intricate patterns, ranging from somewhat over-thickened surface layers where sediment has accumulated locally to small areas of uneroded soils on gentle slopes or severely eroded soils on steeper, convex slopes. Where the original A and/or E horizons were very thick, little or no mixing of underlying material may have taken place.

Class 3.—This class consists of soils that have lost, on average, 75 percent or more of the original A and/or E horizons or of the uppermost 20 cm if the original A and/or E horizons were less than 20 cm thick. In most areas, material below the original A and/or E horizons is exposed at the surface, especially in convex positions in cultivated areas; the plow layer consists entirely or largely of this material. Even where the original A and/or E horizons were very thick, at least some mixing with underlying material generally took place. Despite the generally universal loss of surface soil, some areas exhibit intricate patterns, ranging from somewhat over-thickened surface layers where sediment has accumulated locally to small areas of only slightly eroded soils, generally where slopes are relatively gentle.

Class 4.—This class consists of soils that have lost all of the original A and/or E horizons or the uppermost 20 cm if the original A and/or E horizons were less than 20 cm thick. In most areas, some or all of the deeper horizons have been removed throughout the majority of the area. The original soil can be identified only in small areas. Some areas may be smooth, but most have an intricate pattern of gullies.

Land Cover

The type of land cover around the site where a soil is described should be recorded. As with other descriptive terms, it is best to use standard terms consistently. The NCSS has adopted a set of general terms that includes land cover kinds, such as *artificial cover, barren land, crop cover, shrub cover, grass/herbaceous cover, tree cover,* and *water*. Subtypes within these general classes are also recorded. See Schoeneberger et al. (2012) for the land cover types and subtypes used.

In addition to recording the overall land cover condition at the site, more detailed analysis can be done to provide quantitative estimates of the surface cover at the site. The ground surface of most soils is covered by vegetation to some extent at least part of the year. In addition, rock fragments form part of the mineral material at the surface of many soils. The vegetal material that is not part of the surface horizon and the rock fragments together form the ground surface cover. The proportion of cover, along with its characteristics, is very important in determining a soil's thermal properties and resistance to erosion.

At one extreme, estimation of cover can be made visually without quantitative measurement. At the other extreme, transect techniques can be used to make an almost complete modal analyses of the ground surface. If the ground surface is relatively permanent, more effort in documentation is justified. In many cases, a combination of rapid visual estimates and transect techniques is appropriate.

The ground surface may be divided into fine earth and material other than fine earth. The latter consists of rock fragments and both live and dead vegetation. Vegetation is separated into *canopy* and *noncanopy* (litter). A canopy component has a relatively large cross-sectional area capable of intercepting rainfall compared to the area near enough to the ground surface to affect overland water flow. When determining susceptibility to erosion, both canopy and noncanopy vegetation are considered.

The first step in evaluation is determining the components (typically one to three) of the ground surface cover. A common three-component land surface consists of trees, bushes, and areas between the two. The areal proportion of each component must be established, such as by transect. If a canopy component is present, the area within the tree drip line (edge of where water drips from trees and onto the ground) is determined as a percent of the ground surface. For each canopy component, the effectiveness must be established. *Effectiveness* is the percent of vertical raindrops that would be intercepted. The canopy effectiveness is typically estimated visually, but a spherical densitometer may be used. In addition to the canopy effectiveness, the mulch must be identified for each component.

Transect techniques may be used to determine the mulch percentage. The mulch can be subdivided into rock fragments and vegetation. From the areal proportions of the components and their respective canopy efficiencies and mulch percentages, the soil-loss ratio may be computed for the whole land surface (Wischmeier and Smith, 1978). Other observations may include the percent of kinds of plants, size of rock fragments, amount of green leaf area, and aspects of color of the immediate surface that may affect absorption of radiant energy in an area.

Vegetation

It is important to evaluate and record details about the vegetative community of a site, particularly in non-agricultural settings, such as rangeland, marshes, and forests. Plants reflect the integrated effects of controlling water dynamics, climate, native fertility, human intervention, and other factors upon the soil. Baseline vegetation information centers on the plant species present and the extent of the area that they cover.

Typically, the dominant plant species present are identified and documented in descending order of prominence. The scientific name is used along with, or *in lieu* of, the common name. Common plant names are not preferred as they may not be unique. A species may be known by multiple common names in a region, depending upon local cultures and languages spoken. The appropriate scientific plant symbol (USDA-

NRCS, 2016c) is also recorded, for example, ANGE (*Andropogon gerardii,* or big bluestem). The amount of ground covered by each plant species recorded at the site is also estimated or measured.

Ecological Sites

Soils and natural vegetative communities are generally closely related. For this reason, soil survey efforts commonly include the correlation of soil map unit components with ecological site information for an integrated natural resource inventory. In the United States, the soils are formally correlated to ecological sites (USDA-NRCS, 2016a).

An ecological site is a conceptual division of the landscape. It is defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances. Ecological sites combine soils, climate, landform, vegetation, and hydrology into groupings subject to similar management and with similar response to disturbance. Ecological site descriptions provide characterization information for each site, state-and-transition models (USDA-NRCS, 2016a) that depict vegetation dynamics, and information on use and management. Appendix 4 discusses ecological site assessments.

In determining soil types and ecological sites, the vegetation that was on site during soil formation is very important. Use of soil information for descriptions of ecological dynamics, state-and-transition models, and management recommendations depends upon the best characterization of the vegetation community, including its history and current potential. Soil and vegetation (historic and potential) are the primary criteria for grouping ecosystems or ecosites at finer scales (USDA-FS, 2005). Existing vegetation does not always reflect historic or potential vegetation.

Soil-ecological site correlation establishes the relationship between soil components and ecological sites. Ecological sites are correlated on the basis of soils and the resulting differences in species composition, proportion of species, and total production of the historic climax plant community. In some cases, it is necessary to extrapolate data on the composition and production of a plant community for one soil to describe the plant community on a similar soil for which no data are available. The separation of two distinct soil taxonomic units does not necessarily delineate two ecological sites. Likewise, some soil taxonomic units occur over broad environmental gradients and may support more than one distinctive historic climax plant community. Changes in plant communities may be due to other influences, such as an increase or decrease in average annual precipitation.

Integrated Natural Resource Inventories

Integrated natural resource inventories incorporate several data elements, commonly at a variety of scales and with varying objectives. They typically use soil information as a key data element. Soil data, including maps, commonly provide a basis for spatial identification of combinations of features to define sites. Soil properties derived from soil survey data are grouped spatially and conceptually in logical units based on similarities in vegetative communities and in response to use and management. The concept of "site" has been used for many decades and includes a combination of several biotic and abiotic attributes. Ecological sites provide a conceptual framework in which data can be integrated for use by various agencies of the U.S. Government and other entities.

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