Chapter 8: Soils of the Northwest Central US

It's sometimes easy to take the soil beneath our feet for granted. Yet soil has always been with us—it is the foundation of our houses and roads, and from the soil comes our food, fiber, and paper. Soil is the interface between living earth and solid rock, between biology and geology. The engineer, the scientist, and the gardener may all look at the soil beneath them in different ways, but perhaps no one has a more integral relationship with soil than a farmer. The economic success of producing crops is intimately tied to the quality of the soil upon which those crops grow, and the most successful farmers are well versed in the science of their soil. Soils store and purify water, and they exchange gases with the **atmosphere**. They support agriculture and natural ecosystems and provide a grassy surface for our parks and fodder for our gardens. Everyone, everywhere, every day, depends upon the soil.

What is Soil?

Generally, **soil** refers to the top layer of earth—the loose surface of earth as distinguished from rock—where vegetation grows. The word is derived (through Old French) from the Latin *solum*, which means "floor" or "ground." Soil is one of the most important resources we have—the most basic resource upon which all terrestrial life depends. The Northwest Central has a wide variety of soils, and each type of soil has a story to tell of its origin.

Soils form from the top down, and typically reach a depth of about one meter (3.3 feet) at their more developed stages, although some can reach much deeper. Soils are composed of a mixture of two key ingredients. The first is plant litter, such as dead grasses, leaves, and fallen debris. Worms, bacteria, and fungi do the job of breaking these down into nutritious organic matter that helps soil to nourish future plant growth. The second important component of soil is sediment derived from the **weathering** of rock that is then transported by **wind**, water, or gravity. Both of these components influence the texture (*Figure 8.1*) and consistency of the soil, as well as the **minerals** available for consumption by plants.

All soils might seem alike, but there can be vast differences in soil properties even within small areas! A single acre may contain several different soil types, each with its own assets and drawbacks. Some types of soil are clayey or prone to flooding, while others are stable enough to be used as a foundation for buildings. The most identifiable physical properties of soils are texture, structure, and **color**, which provide the basis for distinguishing soil **horizons**. Texture refers to the percentage of sand, silt, and clay that makes up the soil. Soil textures have specific names, as indicated in *Figure 8.1*.

atmosphere • *a layer of gases surrounding a planet.*

weathering • *the breakdown of rocks by physical or chemical means.*

wind • *the movement of air from areas of high pressure to areas of low pressure.*

mineral • *a naturally occurring solid with a specific chemical composition and crystalline structure.*

color (soil) • *a physical property of soils, influenced by mineral content, the amount of organic material, and the amount of water.*

horizon • *a layer in the soil, usually parallel to the surface, which has physical characteristcs (usually color and texture) that are different from the layers above and below it.*

CHAPTER AUTHOR

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Review

clay • *the common name for a number of very fine-grained, earthy materials that become plastic (flow or change shape) when wet.*

silt • *fine granular sediment most commonly composed of quartz and feldspar crystals.*

sand • *rock material in the form of loose, rounded, or angular grains, and formed as a result of the weathering and decomposition of rocks.*

till • *unconsolidated sediment that is eroded from the bedrock, then carried and eventually deposited by glaciers as they recede.*

loess • *very fine grained, wind-blown sediment, usually rock flour left behind by the grinding action of flowing glaciers.*

biota • *the organisms living in a given region, including plants, animals, fungi, protists, and bacteria.*

parent material • *the original geologic material from which soil formed.*

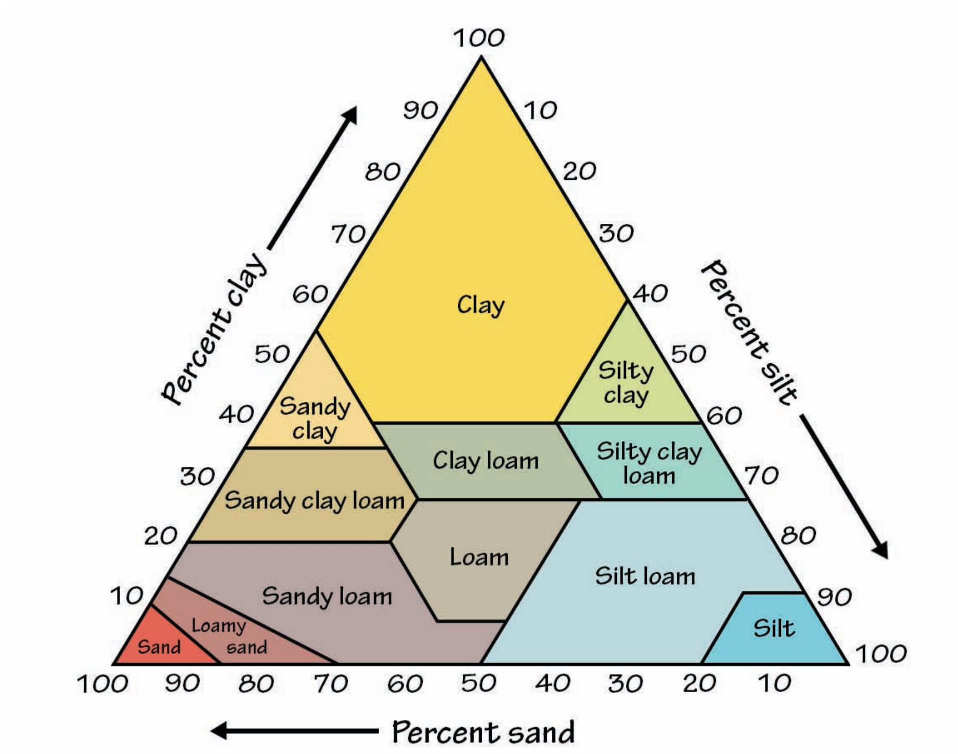

Figure 8.1: Soil texture triangle.

Generally, the best agricultural soils are those with about equal amounts of **clay**, **silt**, and **sand**. A soil of that type is called a **loam**. Soils that are mostly sand do not hold water very well and dry quickly, while soils with too much clay may never dry out. Soil structure refers to the way the soil forms clumps, known as **peds**. Peds are identified by the shape of the soil clods, which take the form of balls, blocks, columns, and plates. These structures are easiest to see in recently plowed fields, where the soil is often granular and loose or lumpy. Soil color is its most obvious physical property. The color is influenced by mineral content, the amount of organic material, and the amount of water it routinely holds. The colors are identified by a standard soil color chart called the Munsell chart.

Five main variables affect the characteristics of soil worldwide. In the Northwest Central, all soils are the products of subtle differences among these five factors:

1. *Parent material* is the original geologic material from which the soil formed. This can be bedrock, preexisting soils, or other materials such as **till**, **loess**, and rock fragments.

2. *Climate* strongly determines the temperature regime, amount of moisture, and type of **biota** that interact with the **parent material**. This affects the extent of chemical and physical weathering on the soil-forming material. For example, if a particular climate lacks precipitation,

mechanical weathering from wind or ice fracturing will predominate. If, however, a climate has abundant precipitation, chemical erosion from water will be accelerated, resulting in substantial leaching.

3. *Topography*, or landscape, of the area is related to the relative position of the soil on the landscape. This includes the presence or absence of hills and the slopes between high and low areas. As the slope increases, water can carry larger sediment sizes, allowing for large sediment loads during major precipitation events. **Topography** also influences natural drainage. Gravity moves water down slopes to depressions or streams and pulls free water downward through the soil. Soils on hills tend to be dry, and soils in depressions and valleys are often wet or saturated. Areas with steep slopes that are susceptible to frequent **erosion** typically have very young soils, as they do not have long to develop before the ingredients are rearranged and the clock is reset. Flatter, more arid areas may have more time to develop, but they have significantly less plant life and will produce a very different soil than will a wetter environment. Slope also frequently determines the types of vegetation covering a soil—for example, different slopes on the same hill might receive varying amounts of sunlight during the growing season—which in turn can cause the characteristics of the soils to diverge if differing forms of vegetation dominate opposite slopes.

4. *Biota or living organisms* that live on or in the material affect soil development through their influence on the amount and distribution of organic matter in the soil. For example, plants contribute significantly to the formation of **humus**, and animals alter a soil's characteristics by leaving behind decayed remains and wastes. Decomposers like bacteria and fungi help to free up the nutrients locked away in these remains and wastes, and these freed nutrients are then recycled and used by new life forms within the same soil. In fact, more than 90% of the nutrients used by a forest in a given year are derived from the decomposition of old organic matter fallen to the forest floor. Animal burrows also create spaces in the soil horizons that allow for deeper penetration of air and water, which, in turn, aid plant development by helping to dissolve mineral nutrients into a form that plants can absorb and process. For its part, organic matter impacts the water-holding capacity of the soil, the soil's fertility, and root penetration.

5. *Time* is required for soils to develop while the four elements mentioned above interact. Older soils have deeper and thicker **subsoils** than do younger soils, but only if other soil forming factors remain constant. In central South Dakota, for example, it takes approximately 500 years to generate a new 2.5 centimeters (1 inch) of **topsoil** beneath the prairie grass—but it only takes a few years for erosion and weathering to destroy the same amount of unprotected topsoil.

Several types of **chemical reactions** are important for soil development; of these, acid-base reactions are some of the most important and complex. When carbon dioxide (CO_2) dissolves in water it forms weak carbonic acid. CO_2 found

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topography • *the landscape of an area, including the presence or absence of hills and the slopes between high and low areas.*

erosion • *the transport of weathered materials.*

humus • *a soil horizon containing organic matter.*

subsoil • *the layer of soil beneath the topsoil, composed of sand, silt and/or clay.*

topsoil • *the surface or upper layer of soil, as distinct from the subsoil, and usually containing organic matter.*

chemical reaction • *a process that involves changes in the structure and energy content of atoms, molecules, or ions but not their nuclei.*

Review

igneous rocks • *rocks derived from the cooling of magma underground or molten lava on the Earth's surface.*

silica • *a chemical compound also known as silicon dioxide (SiO_2).*

aluminum • *a metallic chemical element (Al), and the most abundant metal in the Earth's crust.*

iron • *a metallic chemical element (Fe).*

titanium • *a metallic chemical element (Ti) that is important because of its lightweight nature, strength and resistance to corrosion.*

metamorphic rocks • *rocks formed by the recrystallization and realignment of minerals in pre-existing sedimentary, igneous, and metamorphic rocks when exposed to high enough temperature and/or pressure.*

sedimentary rock • *rock formed through the accumulation and consolidation of grains of broken rock, crystals, skeletal fragments, and organic matter.*

in soil water can come from the atmosphere, where it dissolves in rainwater. Even more CO_2 usually comes from the soil itself, where it is produced by respiring organisms. The amount of CO_2 in soil gases can easily reach levels ten times higher than the amount found in the atmosphere (over 4000 ppm in soil vs. 400 ppm in the atmosphere), making soil water potentially more acidic than rainwater. As this acidic water slowly reacts with fresh minerals, it buffers the soil's pH and keeps it in a range (6–8) preferred by many organisms. Acid-driven weathering breaks down the soil's primary **igneous** minerals, typically transforming them to **silica**-rich clays. As the soil's primary minerals are depleted, it loses the ability to buffer acidity, and the pH of highly weathered soil can drop to around 4. These weathered soils tend to be rich in **aluminum**, **iron**, and **titanium**.

In highly weathered settings, soil loses most of its nutrients, and the store of nutrients that remains is mostly found in organic matter. In weathered soils, only the top 25 centimeters (10 inches) or so may be very biologically active, and rooting depths are very shallow. If this thin layer is lost to erosion, the underlying mineral soil may be infertile and incapable of rapid recovery.

Soil Orders

Just as rocks are classified into different types based on how they formed (igneous, **metamorphic**, or **sedimentary**), their mineral composition, and other characteristics, soils also have their own classification scheme. Soil develops in horizons, or layers, whose formation is dependent on the available ingredients, environmental conditions, and the time it takes to mature. Since the organic and chemical processes that form soils first impact the top of the soil column and then work their way downward, horizontal layers of soil with different characteristics are formed, resulting in divergent colors, textures, and compositions.

A vertical cross-section of all the horizons or layers of soil present in a given area is referred to as a soil profile. Some horizons are completely absent in certain profiles while others are common to most. Each horizon corresponds to a stage in the weathering of rock and decay of plant matter, and each is found at a specific position beneath the surface (*Figure 8.2*). The *O horizon* at the top of the profile contains partially decayed plant material and transitions down to the *A horizon*, which contains mineral matter with a mix of humus and is commonly referred to as topsoil. Below the A horizon lies the *B horizon* or subsoil, which contains mineral material that has leached from above. The *C horizon* at the base of the soil profile contains partially altered parent material.

Soils can also be categorized by their location (northern vs. southern soils), the type of vegetation growing on them (forest soils vs. desert soils), their topographic position (hilltop soils vs. valley soils), or other distinguishing features. The system used to classify soils based on their properties is called **soil taxonomy** *(Figure 8.3)*, and it was developed by the United States Department of Agriculture (USDA) with the help of soil scientists from across the country. It provides a convenient, uniform, and detailed classification of soils throughout the US (*Figure 8.4*), allowing for an easier understanding of how and why different regions have developed unique soils.

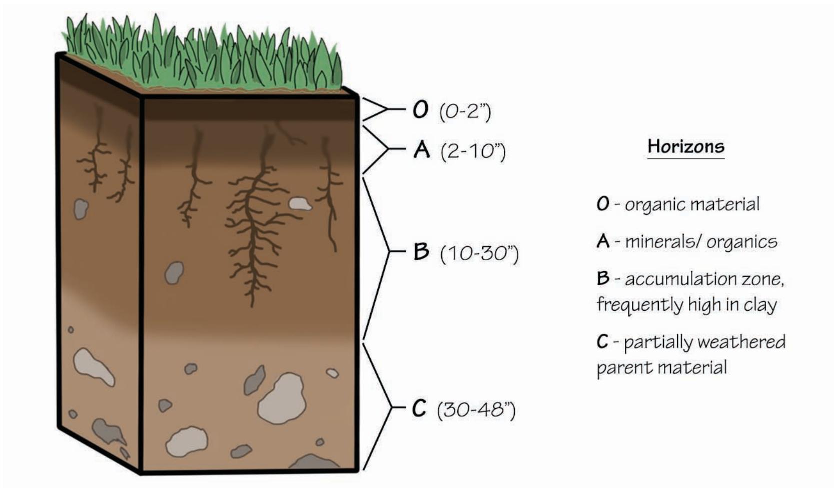

Figure 8.2: A typical soil profile shows the transition from the parent material (horizon C) to the highly developed or changed horizons (O through B). Not every soil profile will have all the horizons present.

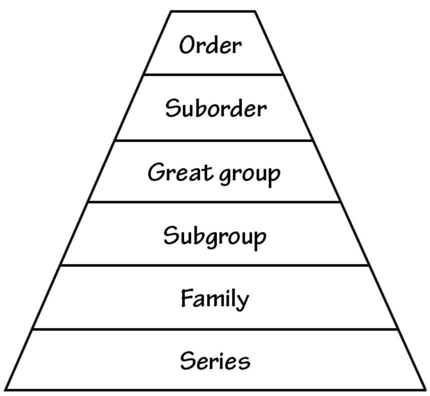

Figure 8.3: Soil taxonomy.

In soil taxonomy, all soils are arranged into one of 12 major units, or **soil orders**. These 12 orders are defined by diagnostic horizons, composition, soil structures, and other characteristics. Soil orders depend mainly on **climate**, parent material, and the organisms within the soil. These orders are further broken down into 64 suborders based on properties that influence soil development and plant growth, with the most important property being how wet the soil is throughout the year. The suborders are, in turn, separated into great groups (300+) and subgroups (2400+). Similar soils within a subgroup are grouped into even more selective families (7500+), and similar soils within families are grouped together into the most exclusive category of all: a series. There are more than 19,000 soil series described in the United States, with more being defined every year.

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soil taxonomy • *the system used to classify soils based on their properties.*

soil orders • *the twelve major units of soil taxonomy, which are defined by diagnostic horizons, composition, soil structures, and other characteristics.*

climate • *a description of the average temperature, range of temperature, humidity, precipitation, and other atmospheric/hydrospheric conditions a region experiences over a period of many years (usually more than 30).*

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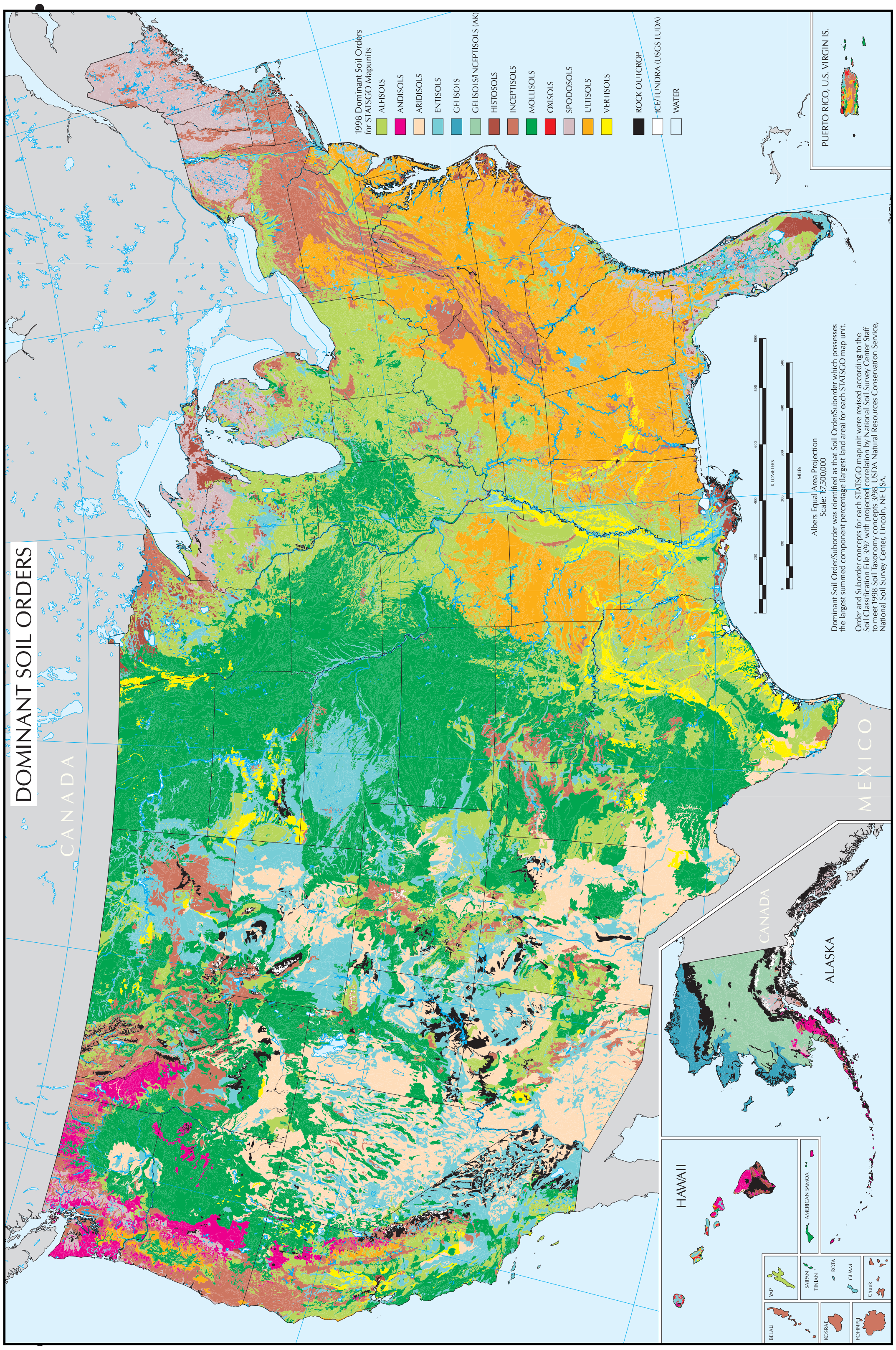

Figure 8.4: Dominant soil orders of the United States. (See TFG website for a full-color version.)

The 12 soil orders

Name	Description	Controlling Factors	Percentage of global ice-free land surface	Percentage of US ice-free land surface
Alfisols	Highly fertile and productive agricultural soils in which clays often accumulate below the surface. Found in humid and subhumid climates.	climate and organisms	~10%	~14%
Andisols	Often formed in volcanic materials, these highly productive soils possess very high water- and nutrient-holding capabilities. Commonly found in cool areas with moderate to high levels of precipitation.	parent material	~1%	~2%
Aridisols	Soils formed in very dry (arid) climates. The lack of moisture restricts weathering and leaching, resulting in both the accumulation of salts and limited subsurface development. Commonly found in deserts.	climate	~12%	~8%

The 12 soil orders (continued)

Entisols	Soils of relatively recent origin with little or no horizon development. Commonly found in areas where erosion or deposition rates outpace rates of soil development, such as flood-plains, mountains, and badland areas.	time and topography	~16%	~12%
Gelisols	Weakly weathered soils formed in areas that contain permafrost within the soil profile.	climate	~9%	~9%
Histosols	Organic-rich soils found along lake coastal areas where poor drainage creates conditions of slow decomposition and peat (or muck) accumulates.	topography	~1%	~2%
Inceptisols	Soils that exhibit only moderate weathering and development. Often found on steep (relatively young) topography and overlying erosion-resistant bedrock.	time and climate	~17%	~10%
Mollisols	Agricultural soils made highly productive due to a very fertile, organic-rich surface layer.	climate and organisms	~7%	~22%

The 12 soil orders (continued)

Oxisols	Very old, extremely leached and weathered soils with a subsurface accumulation of iron and aluminum oxides. Commonly found in humid, tropical environments.	climate and time	~8%	~.02%
Spodosols	Acidic soils in which aluminum and iron oxides accumulate below the surface. They typically form under pine vegetation and sandy parent material.	parent material, climate, and organisms	~4%	~4%
Ultisols	Soils with subsurface clay accumulations that possess low native fertility and are often red hued (due to the presence of iron oxides). Found in humid tropical and subtropical climates.	climate, time, and organisms	~8%	~9%
Vertisols	Clayey soils with high shrink/swell capacity. During dry periods, these soils shrink and develop wide cracks; during wet periods, they swell with moisture.	parent material	~2%	~2%

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Dominant Soils of the Northwest Central

The Northwest Central US contains a diverse variety of soils, and 7 of the 12 soil orders are present there in abundance.

Alfisols are partially leached soils with a high degree of fertility that tend to develop in cooler, more forested environments. They commonly form a band separating more arid areas from humid areas. In the Northwest Central, they are largely associated with the Black Hills of South Dakota and the northern Rockies of Montana (*Figure 8.5*).

Andisols are acidic soils associated with **volcanic ash** and debris deposits. They can be both weakly and heavily weathered soils that contain sediments derived from **volcanic** material. They are especially prevalent in northern Idaho, where they support productive forests (*Figure 8.6*).

Aridisols are very dry soils that form in arid environments. Water content is very low or even nonexistent for most of the year, leading to limited leaching. These soils contain abundant **calcium carbonate**, making them quite alkaline. Commonly found in the rain shadow areas of Wyoming and Idaho (*Figure 8.7*), Aridisols are unsuitable for plants that are not adapted to store water or to survive extreme drought.

Entisols are soils of recent origin with poorly developed horizons, typically formed near **floodplains**. These soils are found throughout the Northwest Central, and are common near major rivers as well as in **periglacial** areas where **glacial** sediment has accumulated (*Figure 8.8*).

Inceptisols are soils with poorly developed horizons that are associated with steep slopes and resistant parent material. These soils are most commonly found on the mountainous slopes of the Rockies (*Figure 8.9*).

Mollisols are the dominant soils of grasslands. The thick, black A horizon makes these soils extremely productive and valuable to agriculture. They are one of the most abundant soil types in the Northwest Central, and have made Nebraska and the Dakotas leaders in crop cultivation and grazing (*Figure 8.10*).

Vertisols are very dark soils, rich in swelling clays. Their distinguishing feature is that they form deeply cracked surfaces during dry periods, but swell again in the wet season, sealing all the cracks. As a result, they are very difficult soils to build roads or other structures on. These soils are commonly associated with exposed marine **shales** in the Dakotas and Montana (*Figure 8.11*).

Review

volcanic ash *• fine, unconsolidated pyroclastic grains under 2 millimeters (0.08 inches) in diameter.*

volcanism *• the eruption of molten rock onto the surface of the crust.*

calcium carbonate *• a chemical compound with the formula $CaCO_3$, commonly found in rocks in the mineral forms calcite and aragonite, as well as the shells and skeletons of marine organisms.*

floodplain *• the land around a river that is prone to flooding.*

periglacial zone *• a region directly next to an ice sheet, which, although never covered by ice, has its own distinctive features.*

glacier *• a body of dense ice on land that does not melt away annually and has sufficient mass to move under its own weight.*

shale *• a dark, fine-grained, laminated sedimentary rock formed by the compression of successive layers of silt- and clay-rich sediment.*

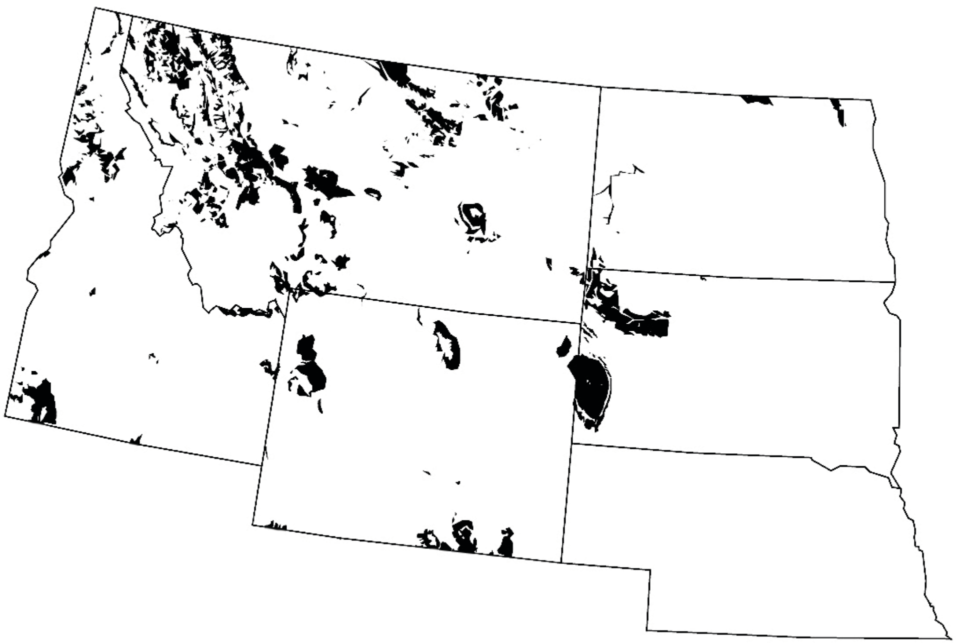

Figure 8.5: Alfisols of the Northwest Central.

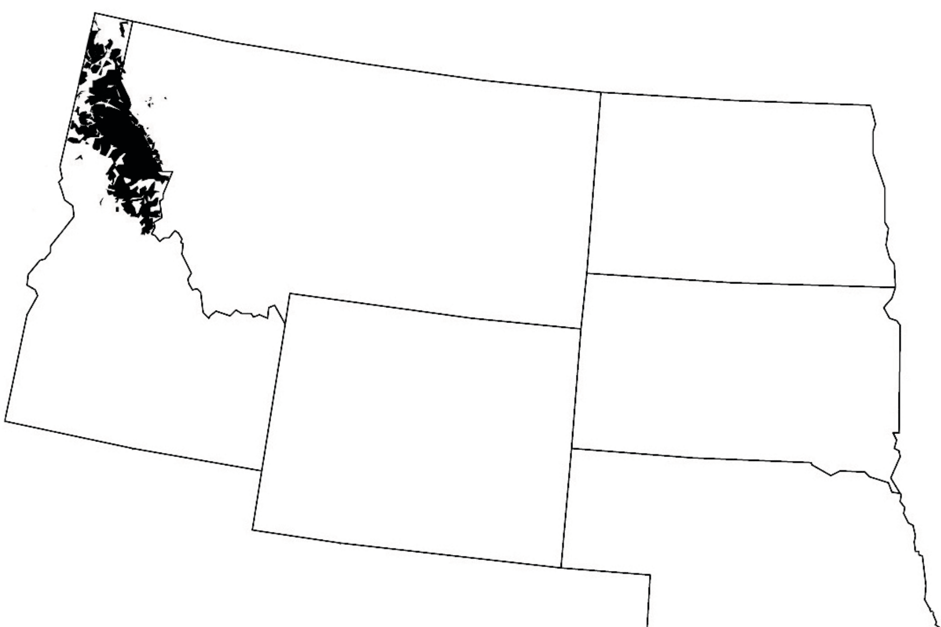

Figure 8.6: Andisols of the Northwest Central.

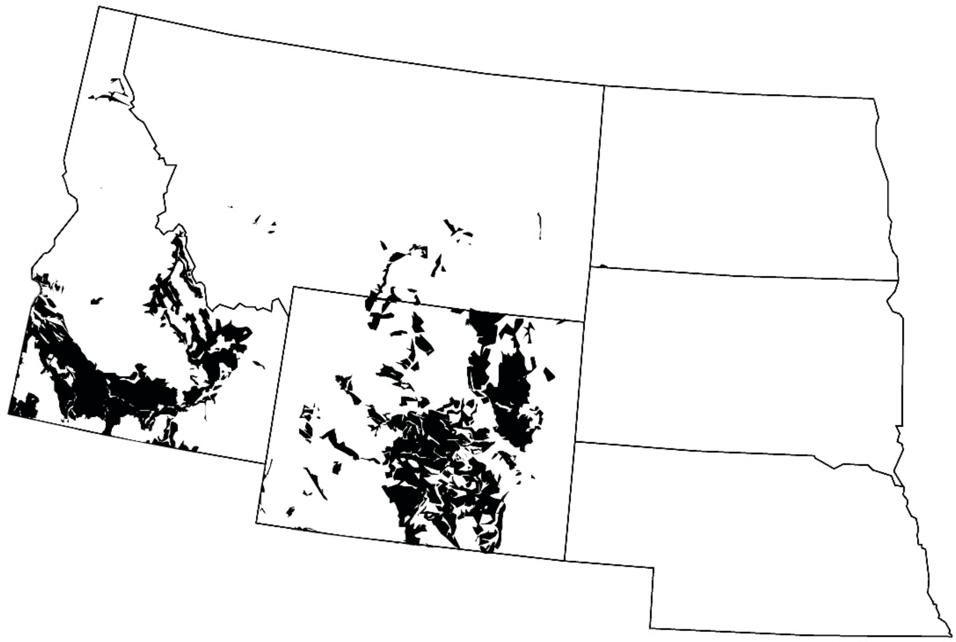

Figure 8.7: Aridisols of the Northwest Central.

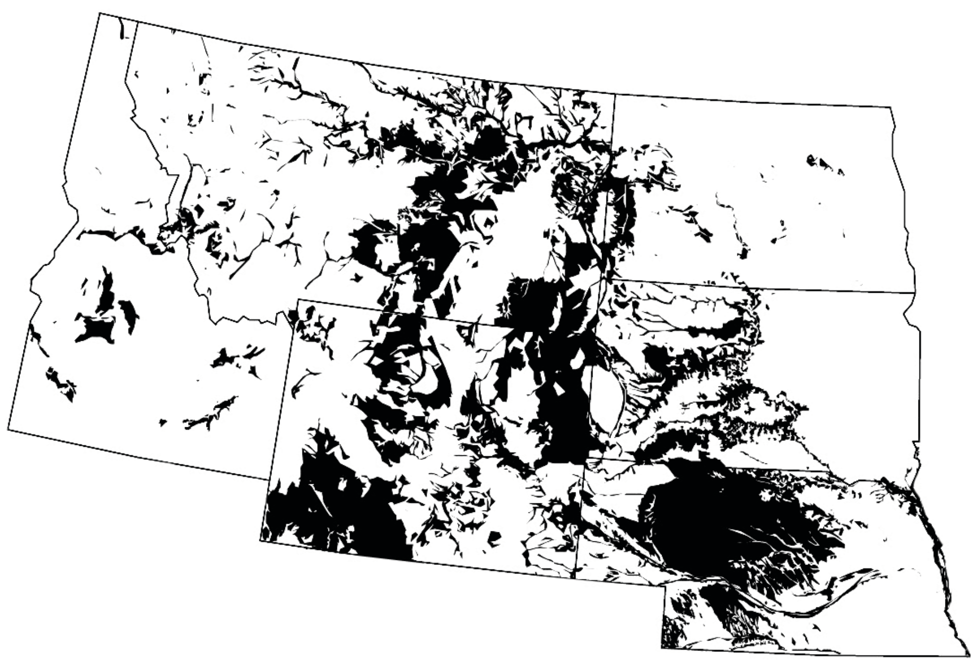

Figure 8.8: Entisols of the Northwest Central.

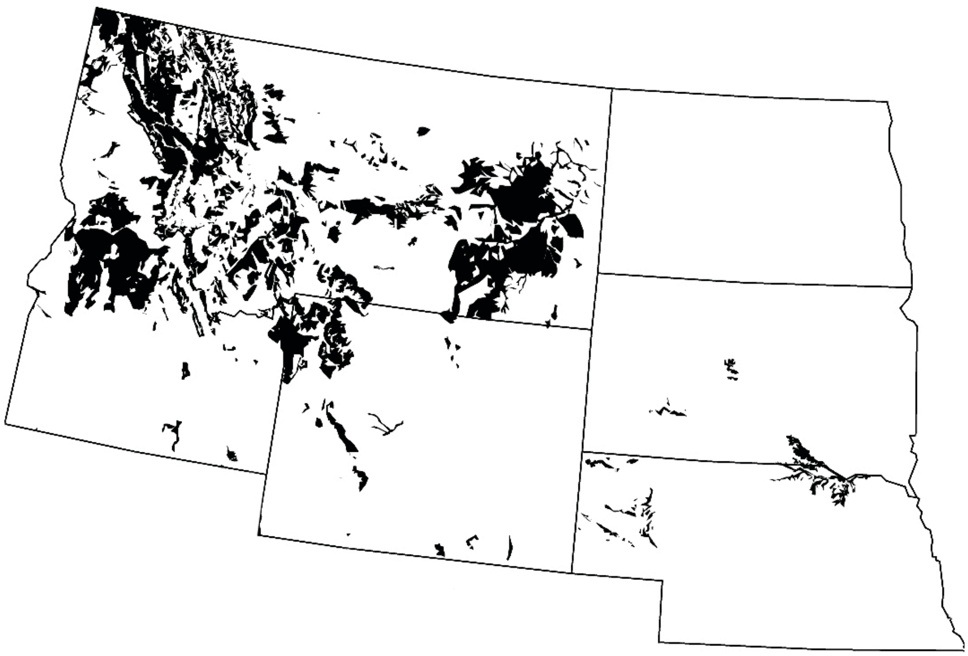

Figure 8.9: Inceptisols of the Northwest Central.

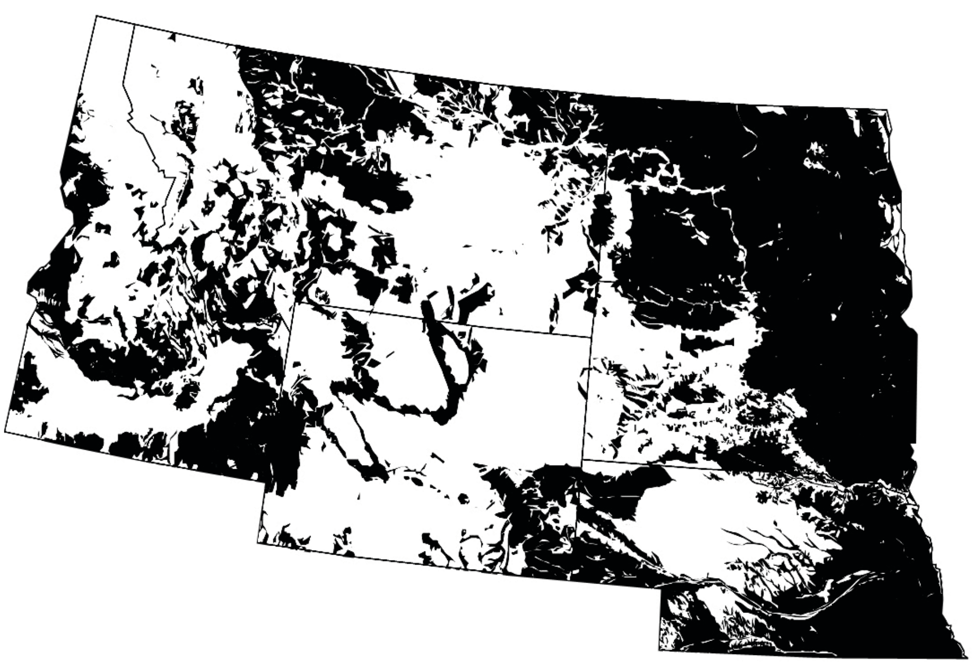

Figure 8.10: Mollisols of the Northwest Central.

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sandstone • *sedimentary rock formed by cementing together grains of sand.*

limestone • *a sedimentary rock composed of calcium carbonate ($CaCO_3$).*

Cretaceous • *a geologic time period spanning from 144 to 66 million years ago.*

Quaternary • *a geologic time period that extends from 2.6 million years ago to the present.*

uplift • *upward movement of the crust due to compression, subduction, or mountain building.*

hot spot • *a volcanic region thought to be fed by underlying mantle that is anomalously hot compared with the mantle elsewhere.*

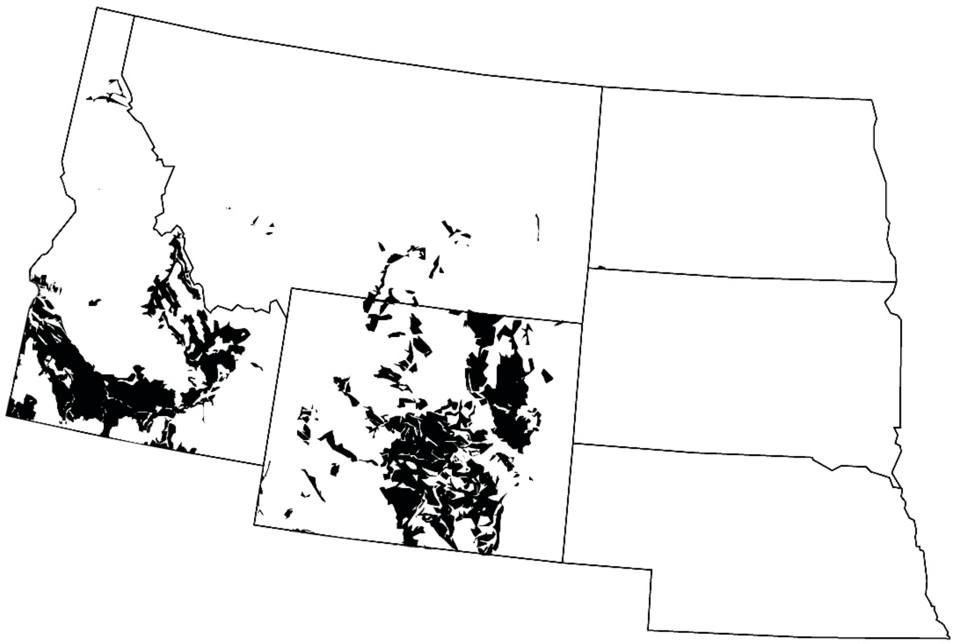


Figure 8.11: Vertisols of the Northwest Central.

Geology of the Northwest Central: Parent Material

The Northwest Central is home to a variety of parent materials—the minerals and organic matter from which its soils are derived (*Figure 8.12*). Mineral material determines a soil's overall fertility, and the vegetation it supports.

Weathered sedimentary rock is perhaps the most ubiquitous parent material in the Northwest Central. **Sandstone**, siltstone, **limestone**, and shale are among the most common bedrocks across the Northwest Central States; over time, erosional processes have contributed to the formation of soils from all of these sedimentary substrates. Much of this rock was laid down during the **Cretaceous**, when the Western Interior Seaway flooded the landscape.

A significant portion of the Northwest Central was also subjected to glaciation during the **Quaternary**, leading to the accumulation of loess deposits (*Figure 8.13*) carried by wind and deposited by river systems. These glacial sediments are responsible for the development of some of the extremely productive agricultural soils found there today.

The soils in the western regions of the Northwest Central are derived largely from igneous and metamorphic rocks. Many of these were generated during the tectonic events that led to the **uplift** of the Rocky Mountains, while others are related to volcanism at the Yellowstone **hot spot**.

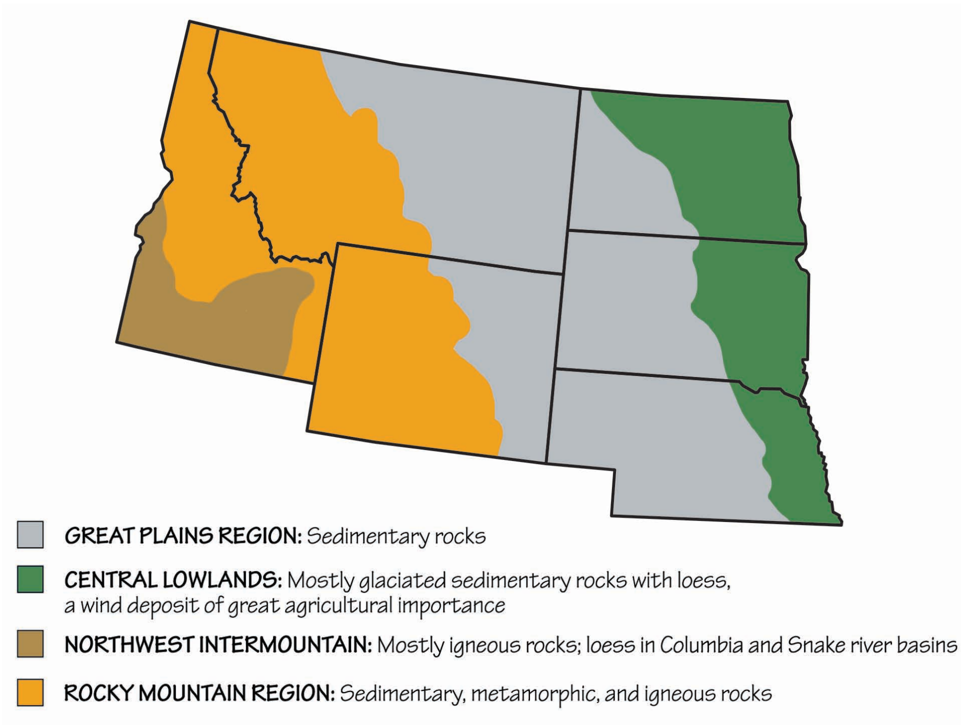


Figure 8.12: Physiographic and regolith map of the South Central.
(See TFG website for full-color version.)

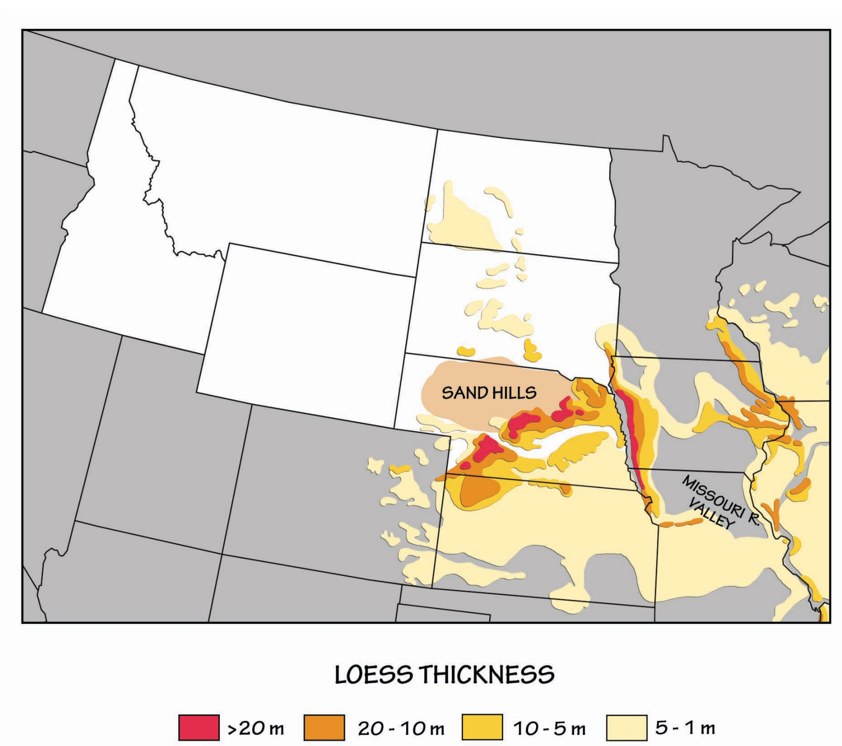


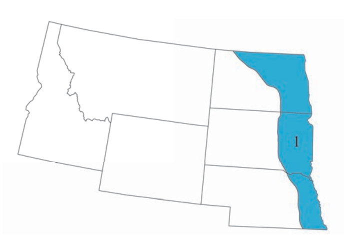
Figure 8.13: Loess deposits in the Northwest Central and surrounding states.
(See TFG website for full-color version.)

8 Soils

Region 1

relief *• the change in elevation over a distance.*

hectare *• a metric unit of area defined as 10,000 square meters.*



Soils of the Central Lowland
Region 1

The Central Lowland is a broad and mostly flat expanse of the North American interior, stretching approximately 2400 kilometers (1500 miles) across its east-west diameter. Recent glaciation has repeatedly ground down any preexisting topographical **relief**, burying the region's pre-glacial geology in a layer of unsorted sediment and windblown loess that was carried and processed by the advance and retreat of continental glaciers. The combination of low levels of topographical relief, recent glacial deposits of till, and the dominance of a tall grassland ecosystem has produced remarkably rich and fertile soils with high agricultural value.

Mollisols are the dominant soil type in the Central Lowland region, formed where organic matter accumulates beneath prairie grasses and in poorly drained forests. In many cases, these soils are underlain by thick deposits of glacial loess, which has contributed to their rich nutrient content (*see Figure 8.13*). Mollisols are highly productive dark soils (*Figure 8.14*), and most of the native grassland that produces them has been converted to agricultural land. Tallgrass prairie once covered more than 69 million **hectares** (170 million acres) of North America, but today nearly 96% of it has been converted for agriculture. The eastern Dakotas and eastern Nebraska contain some of the most productive land in the world. Thanks to fertile Mollisols, these states are national leaders in the production of corn, soybeans, wheat, flaxseed, rye, sorghum, oats, hay, alfalfa, and barley. All three states are generally ranked at or near the top ten in annual yield of these crops, and also support a robust livestock and dairy industry along with the bulk of the nation's honey production.

Figure 8.14: A farmer ploughs a field of rich, dark Mollisols in North Dakota's Red River Basin.

The Mollisols of the Central Lowland reflect a climatic gradation from wetter to drier conditions. The dominant Mollisols found in the region, especially in the Red River Valley and near the Missouri and Platte rivers, are wetter and occur close to the **water table.** Southeastern South Dakota and northeastern Nebraska contain drier Mollisols that form under semi-arid climates.

Entisols, young soils lacking in horizons, are found where erosion and deposition occur faster than the rate of soil formation. In the Central Lowland, they typically appear in floodplains where **alluvial** sediments are deposited. They are prevalent along the Platte and Missouri rivers in Nebraska.

Wet Vertisols, which remain saturated for large parts of the year but occasionally dry out enough to form cracks, can be found all throughout North Dakota's Red River Valley.

Soils of the Great Plains
Region 2

The Great Plains, a broad plateau that is home to intermediate and short grasslands, stretches for 3200 kilometers (2000 miles) from the Canadian interior south to the Mexican border. Its 800-kilometer (500-mile) wide expanse is sandwiched between the Central Lowland and the **Canadian Shield** to the east and the Rocky Mountains to the west.

Conditions in the Great Plains become increasingly drier as one travels from east to west. Highly fertile Mollisols with a thick, black top horizon are found in the region's eastern extent. These soils allow for the greatest productivity and are often associated with intensive agricultural operations. As one moves westward, decreasing moisture and vegetation impacts soil development, making soils thinner and less productive, which naturally produces shorter grasses (*Figure 8.15*). The central Great Plains are dominated by dry Mollisols belonging to the suborder Ustolls, which form in semi-arid conditions. These soils can become even more dusty and dry during drought conditions (*Figure 8.16*), limiting crop yields and leading to damaging dust storms such as those that occurred during the Dust Bowl of the 1930s. In the western Dakotas, western Nebraska, eastern Montana, and eastern Wyoming, the decreased precipitation and lower soil fertility provides for a localized agricultural economy based heavily in rangeland livestock—these states are leaders in the production of beef cattle and sheep. Crops here often require irrigation from local **aquifers** or various surface water impoundments.

In many western areas of the Great Plains, the soils are heavily influenced by existing sedimentary rock material lain down during the uplift of the Rockies and the deposition of **Mesozoic** sediments. The erosion of exposed Cretaceous marine shales produces Vertisols, soils that experience drastic fluctuations in volume when exposed to water (*Figure 8.17*). Locals refer to such soil as "gumbo" and consider it to be unworkable and impassable when wet. It is also

water table • *the upper surface of groundwater.*

alluvial • *a thick layer of river-deposited sediment.*

Canadian Shield • *the stable core of the North American continental landmass, containing some of the oldest rocks on Earth.*

aquifer • *a water-bearing formation of gravel, permeable rock, or sand that is capable of providing water, in usable quantities, to springs or wells.*

Mesozoic • *a geologic time period that spans from 252 to 66 million years ago.*

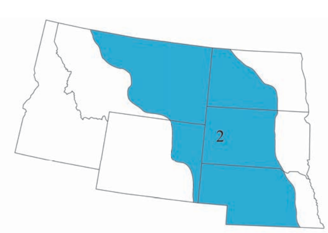
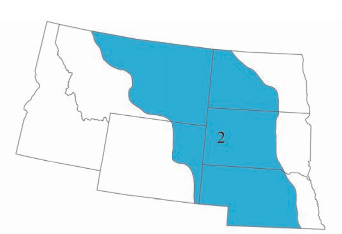


Figure 8.15: Seemingly endless stretches of rolling short and intermediate grasses dominate the drier soils of the Great Plains.

Figure 8.16: Dust rises from dry Ultisols in the Great Plains' Prairie Pothole Region.

Figure 8.17: Cracked Vertisols in central Montana.



Region 2

a major engineering concern for structures involving roads and buildings due to its predisposition to shifting and developing **creep** or slow mass movement of earth. This same shifting ability discourages the formation of any distinct horizons. Clayey Vertisols are highly alkaline and water restrictive, inhibiting crop yields and forcing most agricultural usage into rangeland grazing.

Alfisols are scattered throughout Montana as well as concentrated in the Black Hills of South Dakota. These soils generally form in forested areas as a result of weathering processes that leach minerals from the surface layer into the subsoil, where nutrients are retained. The Black Hills' unique geology makes them a forested oasis amidst a sea of grassland—and perfectly suited to the development of Alfisols.

See Chapter 2: Rocks to learn more about Black Hills geology.

Aridisols are present throughout Wyoming on the western edge of the Great Plains, approaching the Rocky Mountains. These soils, which have no viable agricultural use, occur where the ground remains dry throughout most of the year due to limited precipitation. Consequently, Aridisols show very little evidence of leaching, and they contain abundant accumulations of clay. The Powder River Basin in eastern Wyoming, which receives 23–51 centi-meters (9–20 inches) of precipitation each year, is one example of an arid expanse dominated by Aridisols.

Entisols, young and unstable soils lacking in horizons, are found where erosion and deposition occur faster than the rate of soil formation. Both the soils that overlay loess structures in eastern Nebraska and the rapid erosional surfaces of the Badlands of South Dakota, North Dakota, Montana, and Wyoming exhibit similar Entisol characteristics (*Figure 8.18*). In the Sandhills of north-central Nebraska and south-central South Dakota, the underlying Ogallala Formation's sandy **conglomerate** has contributed to the sediment load needed to form the **aeolian** or windblown formations found in the area. Fully 52,000 square kilometers (20,000 square miles) of land is covered in sand dunes and sand sheets, which were largely created from windblown material eroded by glaciers during the late **Pleistocene**. Recent surveys of the dunes, which are currently covered with a thin veneer of grassland vegetation, have suggested that they were active within the last several thousand years, and may become active again in the event of a severe drought.

See Chapter 4: Topography for more information about the Sandhills.

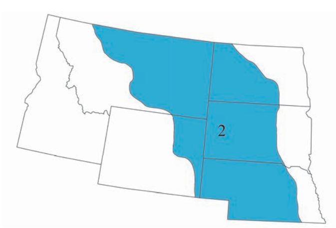
Inceptisols can be found scattered throughout grasslands and lightly forested areas in Montana, South Dakota, and Nebraska.

creep *• the slow movement or deformation of a material under the influence of pressure or stress.*

conglomerate *• a sedimentary rock composed of multiple large and rounded fragments that have been cemented together in a fine-grained matrix.*

aeolian *• pertaining to, caused by, or carried by the wind.*

Pleistocene *• a subset of the Quaternary, lasting from 2.5 million to about 11,700 years ago.*



8 Soils

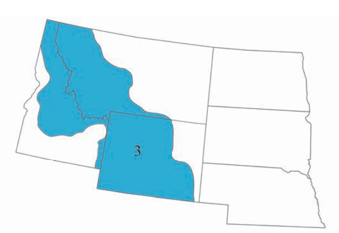
Regions 2–3

Laramide Orogeny • *a period of mountain building that began in the Late Cretaceous, and is responsible for the formation of the Rocky Mountains.*

Figure 8.18: The Badlands of South Dakota form new soil quickly due to the phenomenal average erosion rate of approximately 2.5 centimeters (1 inch) per year.

Soils of the Rocky Mountains
Region 3

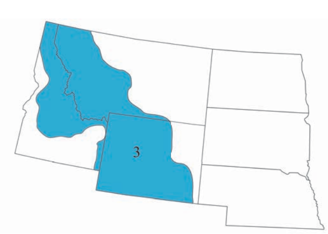
The Rocky Mountains, a series of at least 100 different mountain ranges that stretch some 4800 kilometers (3000 miles) from northern Alberta southward to New Mexico, make up the great western backbone of the North American continent. The history of the uplift that formed the Rockies is complex, but the bulk of mountain building appears to have occurred during the **Laramide Orogeny**, which experienced its peak activity between 70 to 50 million years ago. Many of this region's soils, especially those in the Northern and Middle Rocky Mountains (Idaho, Montana, and northeastern Wyoming), are poorly developed and thin because they have not had sufficient time to develop.



Since Entisols are commonly associated with steep slopes and poorly developed soils, it is easy to imagine why this soil type would be abundant in the Rocky Mountain region. The Bighorn Mountains and Wind River Range of Wyoming and the Big Belt Mountains of central Montana host abundant Entisols. These soils frequently have little agricultural value due to their poorly developed nature and rocky settings, but some high valley systems with sufficient water or irrigation resources can be productive (*Figure 8.19*). However, Entisols are not always directly associated with mountain slopes. The Killpecker Sand Dunes of the Red Desert in southwestern Wyoming provide a stunning example of poorly developed soils periodically disturbed by active and reactivated sand dunes (*Figure 8.20*). These dunes, which formed from collected glacial sediments, are part of the largest active dune field in the United States.

Figure 8.19: The Entisols of high mountain alpine environments support a remarkable variety of forbs and other plant species.

Figure 8.20: The Killpecker Sand Dunes, Wyoming.

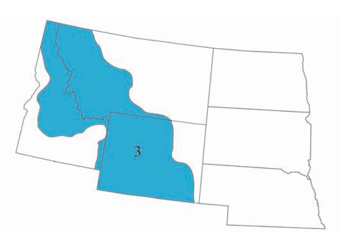


intermontane • *between or among mountains.*

While Inceptisols represent a level of soil development one step above that of Entisols, they are still very poorly developed. Inceptisols are found on reasonably steep slopes and involve parent rock material that is quite resistant to weathering, so they are frequently associated with mountain formations (*Figure 8.21*). Both the Clearwater and Salmon River mountains of Idaho and the Bitterroot Range, which straddles the Montana and Idaho border, host a high concentration of these soils. Many of the Inceptisols in this region are associated with forestry, rather than crop cultivation. The thin, rocky nature of the soils prevents significant water retention, placing lower limits on timber production.

Figure 8.21: Castle Peak, in Idaho's White Cloud Mountains, erodes to form weathered Inceptisols.

Aridisols are commonly found in the **intermontane** Wyoming Basin, due to the influence of a rain shadow effect from the tall mountains to the west. The Red Desert, a high-altitude desert and sagebrush steppe, hosts an abundance of these poorly developed and unstable soils. While many Aridisols are beyond the practicality of common agricultural and economic practices, not all have been left undeveloped. With major irrigation projects such as the Shoshone Project, which irrigates nearly 40,000 hectares (100,000 acres) of crop and grazing land with dammed flood waters from the Shoshone River, large portions of the rain-shadowed Bighorn Basin have proven to be quite productive, yielding soybeans, alfalfa, barley, oats, corn, sugar beets, and pastureland used to support local livestock production.



Andisols are soils formed from volcanic ash and a varied assortment of volcanic ejecta (*Figure 8.22*). Globally, they are the least common order, making up less

Figure 8.22: An example of an Andisol soil. These soils are formed from volcanic materials.

Figure 8.23: An Alfisol soil from the forests of Montana.

__conifer__ • a woody plant bearing cones that contain its seeds.

__plates__ • large, rigid pieces of the Earth's crust and upper mantle, which move and interact with one another at their boundaries.

than 1% of all soil coverage. Similarly, in the US, they represent a mere 1.7% of total soil coverage. However, in the Rocky Mountain region, they are commonly found in the Clearwater, Coeur D'Alene, and Cabinet Mountains of Northern Idaho. These soils support some of the most productive **conifer** forests in the United States due to their unique chemical and physical properties. Andisols frequently contain high concentrations of volcanic glass and various weathered iron- and silica-rich material. Andisols have a high capacity for water retention and often fix large amounts of phosphorus, making it unavailable to plants.

Scattered Alfisols support forests throughout the Rockies of western Montana (*Figure 8.23*), and the high mountains of Montana and Wyoming also contain rich Mollisols that support rangeland and forest vegetation.

Soils of the Columbia Plateau
Region 4

The Columbia Plateau region forms an intermontane plateau bordered by the Northern Rocky Mountains to the east and the Cascade Range to the west. The plateau covers approximately 260,000 square kilometers (100,000 square miles) in Idaho, Oregon, and Washington and is one of the world's largest accumulations of volcanic rock.

The Snake River Plain that stretches in a bow across southern Idaho was formed by volcanic eruptions starting 11 to 12 million years ago. The eastern Snake River Plain follows the path the North American **plate** has taken over the

Region 4

__salt__ • a mineral composed primarily of sodium chloride (NaCl).

__basalt__ • an extrusive igneous rock, and the most common rock type on the surface of the Earth.

Yellowstone hot spot, which is now currently underneath Yellowstone National Park. This area is blocked by mountains on all sides, and therefore moisture is limited, leading to an accumulation of calcium carbonate and various **salts** and clays that form Aridisol soils (*Figure 8.24*). The Aridisols of the Snake River Plain have proven to be quite productive when heavily irrigated, and they compose much of Idaho's agricultural land. This is possible because of the relatively flat nature of the high plain, making crop cultivation practical when water is available. Irrigation yields crops such as potatoes, corn, wheat, sugar beets, mint, alfalfa, and onions. When not irrigated, these Aridisols usually support a sagebrush steppe.

See Chapter 2: Rocks for more information about Yellowstone National Park.

Figure 8.24: Aridisols of Idaho's Snake River Plain, near Craters of the Moon National Monument.

Mollisols, with their dark surface horizon, are common on the periphery of the Snake River Plain and along the western Idaho border in central Idaho. Due to the semiarid conditions of the region, irrigation is still necessary to take advantage of the rich, well-developed soil. Unirrigated Mollisols in the area tend to support a sagebrush steppe environment as well. It is important to note, however, that northwestern Idaho has some of the richest dryland wheat and pulse production in the world. This level of productivity is possible because these particular Mollisols are formed on loess overlying the **basalt**.

Regions 4–5

In southwestern Idaho, the juniper-pinyon woodlands found on rocky or **gravelly** uplands host a concentration of Alfisols. These Alfisols have a subsurface horizon with accumulated clays. Alfisols can be productive soils, and agriculture here is practiced largely in the form of grazing where sufficient sagebrush steppe is available.

Entisols associated with floodwater and **fluvial** deposits are found scattered along the extent of the Snake River.

gravel *• unconsolidated, semi-rounded rock fragments larger than 2 millimeters (0.08 inches) and smaller than 75 millimeters (3 inches).*

fluvial *• see outwash plain: large sandy flats created by sediment-laden water deposited when a glacier melts.*

Soils of the Basin and Range
Region 5

The Basin and Range covers a vast area of the western United States from northwestern Mexico to southern Idaho. Even though the region is generally arid, the portion of the Basin and Range that extends into southeastern Idaho is cooler and higher in elevation than the Snake River Plain to the north, receiving more moisture and supporting more heavily forested terrain.

Mollisols are the most common soil here, and they support a high-elevation sagebrush steppe, shrubland, and forest. Slopes facing the north support forests consisting of Douglas fir, subalpine conifers, aspen, and lodgepole pine. Slopes facing to the south support sagebrush and various grasses. In broad open areas, grassland is prevalent, and is often used for grazing. In areas with less topographical relief, Idaho's Mollisols support dry land or irrigated farming, which is dominated by potatoes.

Inceptisols and Entisols can also be found in this region. Higher elevations support forested slopes with a mixture of conifer species. These soils are commonly associated with the newly formed soils of mountainous terrain and do not lend themselves well to agriculture due to their poor development.

fossil • *preserved evidence of ancient life.*

moraine • *an accumulation of unconsolidated glacial debris (soil and rock) that can occur in currently glaciated and formerly glaciated regions.*

State Soils

Just as many states have official state flowers, birds, and **fossils**, they also have official soils. State soils are most often determined by a vote of soil scientists in the state, and, absent any political wrangling, usually represent the most productive soils and those that most closely resemble everyone's favorite soil: loam. As mentioned earlier, loam soils are almost equal parts sand, silt, and clay.

Idaho

The state soil of Idaho is the Threebear series. A type of Andisol, it is formed from silt and volcanic ash, resulting in a silty loam. These soils are found on hill slopes with a 5% to 35% grade and are associated with timber production.

Montana

Scobey soils are Mollisols that are found in north-central Montana and cover more than 280,000 hectares (700,000 acres) of till plains and **moraines**. These soils consist of brown clay loam and are ideal for growing wheat, which dominates the region's agriculture.

Nebraska

In south-central Nebraska, Holdrege soils cover nearly 810,000 hectares (two million acres) of land and support cropland and rangeland. These Mollisols formed from calcareous and silty loess material, and commonly support crops of soybeans, corn, and wheat.

North Dakota

The state soil of North Dakota is the Williams series, light gray to brown loamy Mollisols. These soils are widely found throughout the state on more than 810,000 hectares (two million acres) of land. Hilly areas of this soil are used for grazing, while level areas are used to produce flax, sunflowers, barley, oats, and wheat.

South Dakota

Houdek soil, a deep, loamy Mollisol, is the state soil of South Dakota. Found throughout the East River area of South Dakota, this grassland soil is heavily developed for agricultural purposes.

Wyoming

Forkwood soils are brown, clay loam Aridisols that are derived from the slopewash alluvium of shales and sandstone. These soils are primarily used for wildlife or grazing livestock.

Resources

General Books and Articles on Soils

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General Websites on Soils

K–12 Soil Science Teacher Resources, Soil Science Society of America, http://www.soils4teachers.org/.

Soil Survey Reports (by state and county/parish), The Cooperative Soil Survey, http://soils.missouri.edu/survey/selectstate.asp.

Soil Sustains Life, Soil Science Society of America, https://www.soils.org.

Soils Tutorial, The Cooperative Soil Survey, http://soils.missouri.edu/tutorial/index.asp.

The Twelve Soil Orders Soil Taxonomy, University of Idaho College of Agricultural and Life Sciences, http://www.cals.uidaho.edu/soilorders/.

USDA Natural Resources Conservation Service: Soils, http://www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home/. (Soil surveys by state, technical publications, soil data, and much more.)

Soils of Specific Parts of the Northwest Central

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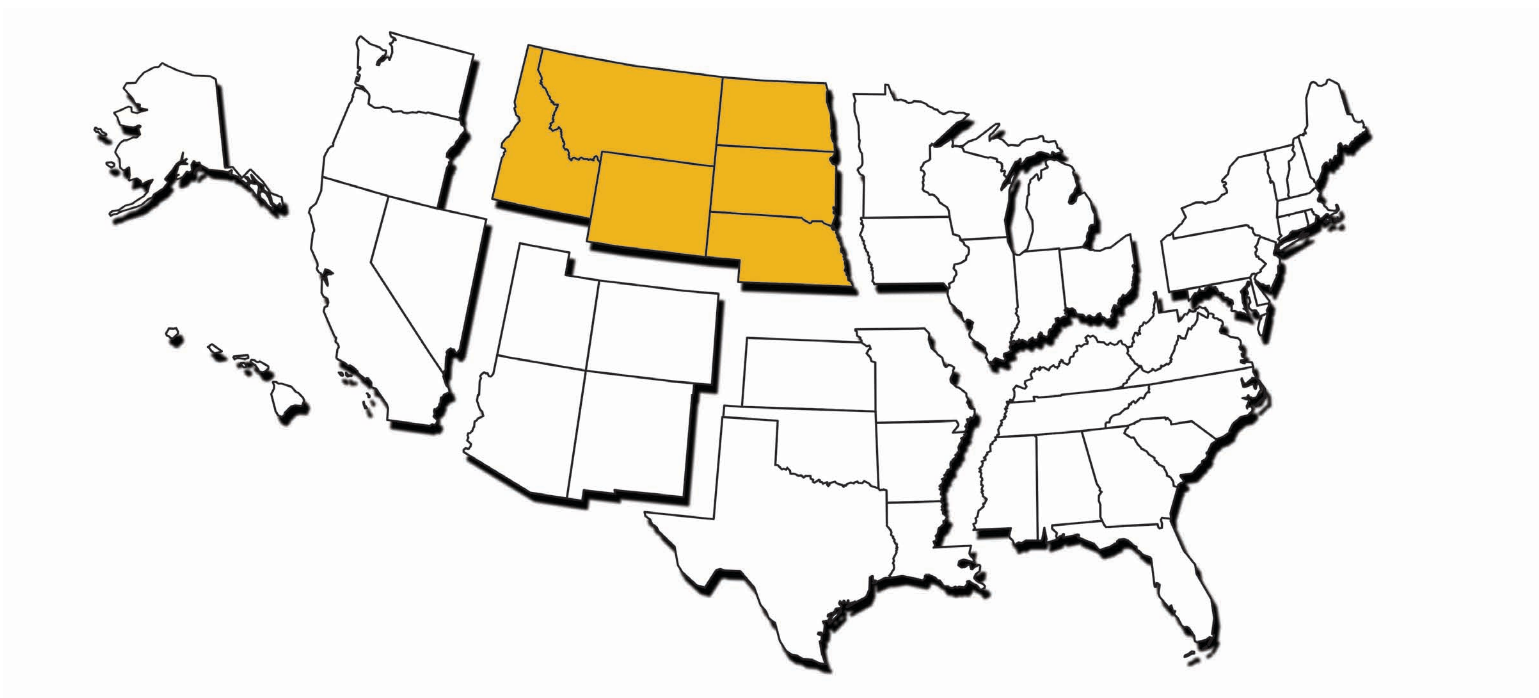

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On the back cover: Blended geologic and digital elevation map of the Northwest Central US. Each color represents the age of the bedrock at the surface. Adapted from Barton, K.E., Howell, D.G., Vigil, J.F., *The North America Tapestry of Time and Terrain*, US Geological Survey Geologic Investigations Series I-2781, http://pubs.usgs.gov/imap/i2781.