# Chapter 7: Soils of the Southwestern 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 Southwest 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 7.1*) 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 7.1*.

***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 it routinely holds.*

***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 AUTHORS

**Richard A. Kissel**
**Judith T. Parrish**

# 7 Soils

## 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.*

***loam*** *• a soil containing equal amounts of clay, silt, and sand.*

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

***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.*

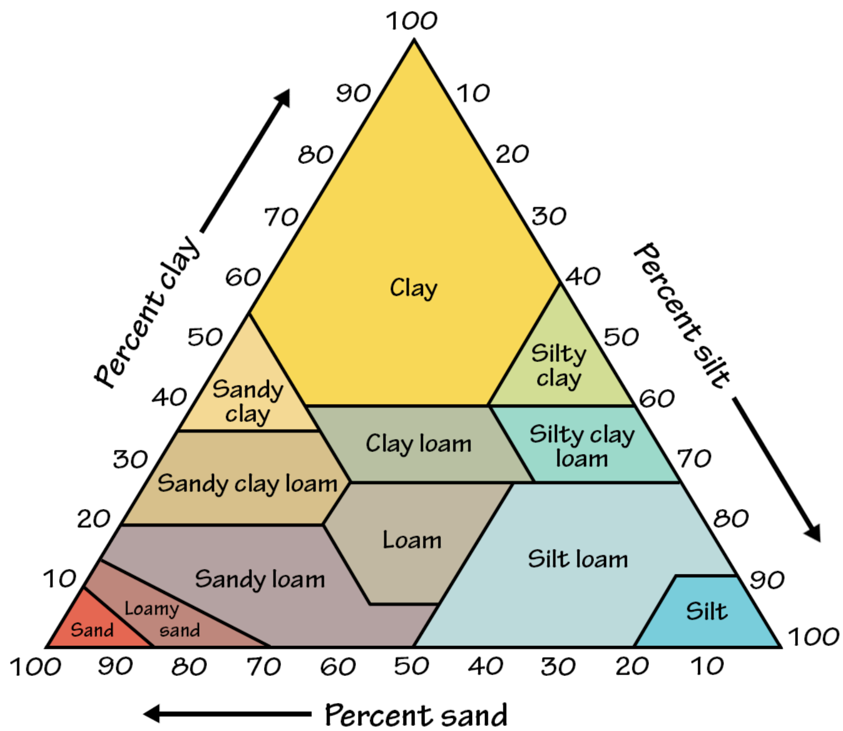


*Figure 7.1: Soil texture triangle.*

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 Southwest, 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 **alluvium**, rock fragments, and windblown sediment.

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 northeastern Colorado, 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 in soil water can come from the atmosphere, where it dissolves in rainwater.

## Review

***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).*

***erosion*** *• the transport of weathered materials.*

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

***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.*

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 10 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 7.2*). 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 7.3)*, 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 7.4*), allowing for an easier understanding of how and why different regions have developed unique soils.

***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.*

# Soils

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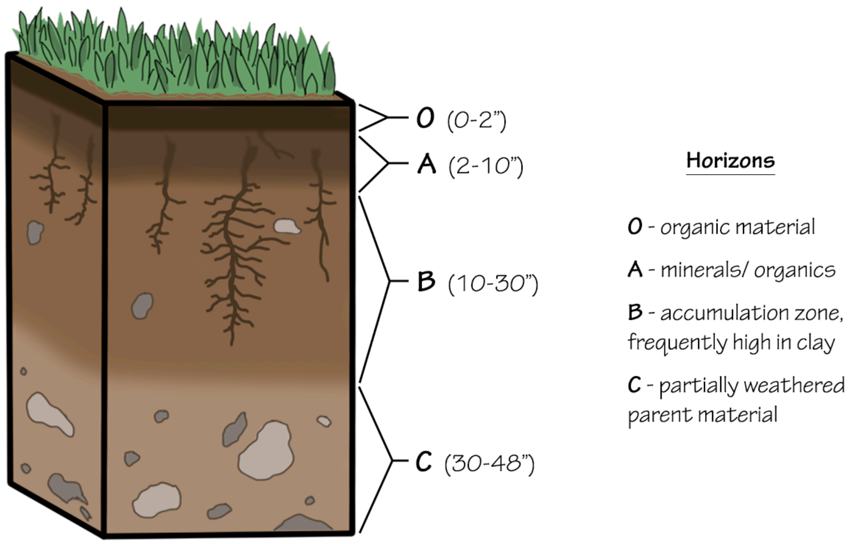


*Figure 7.2: A typical soil profile shows the transition from the parent material (horizon C) to the highly developed or changed horizons (O through B). Not every soil profile will have all the horizons present.*

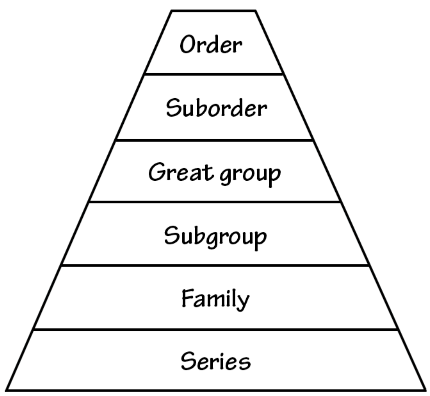


*Figure 7.3: Soil taxonomy.*

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.

## Soil Orders

***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.*

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# Soils

## Soil Orders

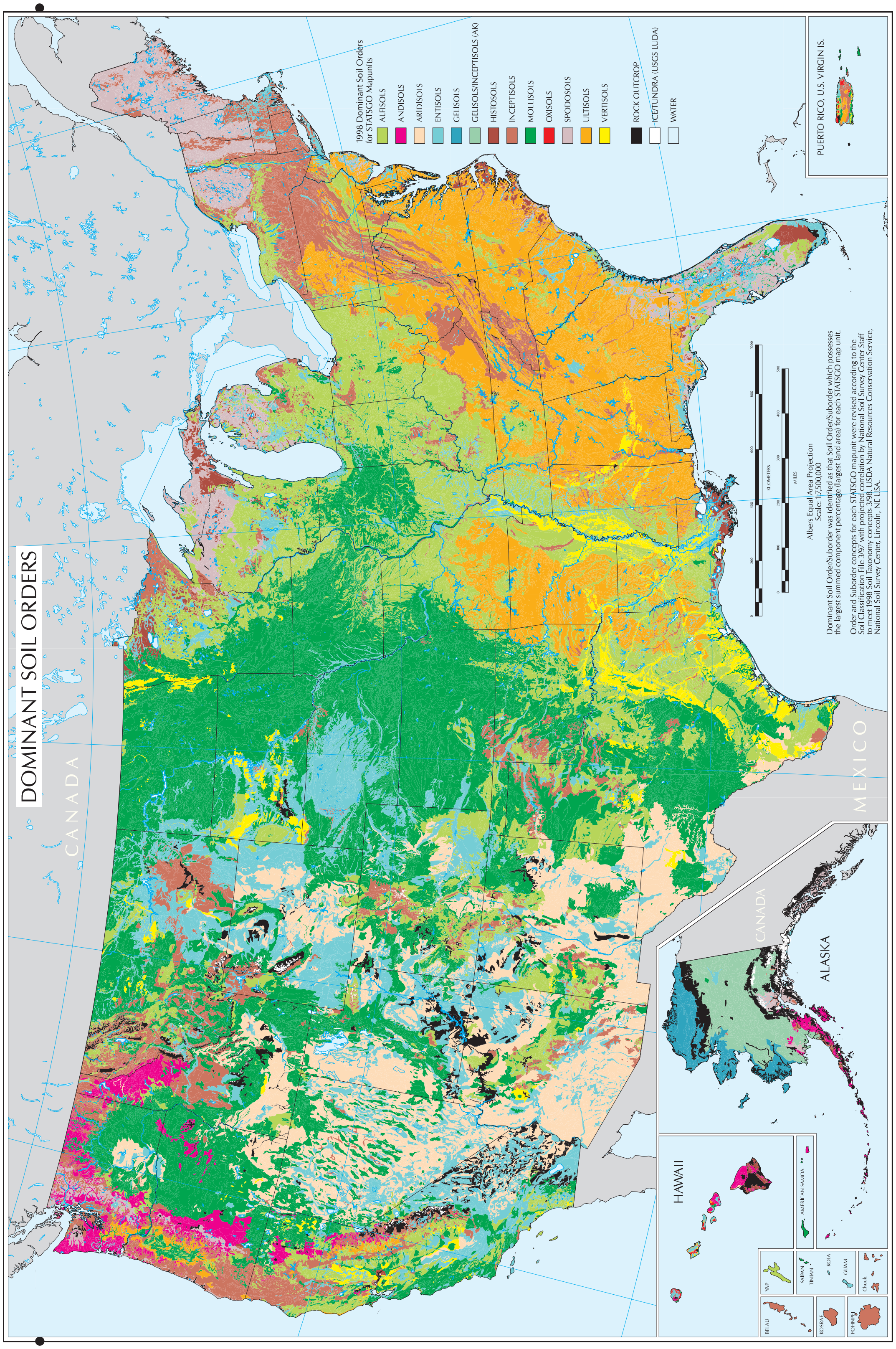


*Figure 7.4: Dominant soil orders of the United States. (See TFG website for a full-color version.)*

**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% |

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# Soils

## Soil Orders

| | | | | |
|---|---|---|---|---|
| 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% |

Soil Orders

| | | | | |
|---|---|---|---|---|
| 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% |

# 7 Soils

## Soil Orders

***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.***

***hyperthermic* • *soils in which the mean annual temperature 50 centimeters (20 inches) below the surface is at least 22°C (71.6°F), with 5 or more degrees variation between winter and summer.***

### Dominant Soils of the Southwest

Six soil orders are found in the Southwest, with the greatest diversity found within the Basin and Range.

**Alfisols** are partially leached soils with a high degree of fertility, in which clays often accumulate below the surface. They tend to develop in cooler, more forested environments, and commonly form a band separating humid areas from more arid areas. In the Southwest, they occur primarily at higher elevations (*Figure 7.5*).

**Aridisols** are very dry soils that form in arid environments, such as the Basin and Range region. Water content is very low or even nonexistent for most of the year, leading to limited leaching. The lack of leaching means that there is abundant **calcium carbonate** in these soils, making them quite alkaline. This soil type is unsuitable for plants that are not adapted to store water or to survive extreme drought. Because of the Southwest's dry climate, Aridisols are the most abundant soil type there (*Figure 7.6*).

**Entisols** are soils of recent origin with poorly developed horizons, typically formed near **floodplains** and on recent erosional surfaces. These soils are found throughout the Southwest in association with river courses, rapid erosion, and wind-transported sediment (*Figure 7.7*).

**Inceptisols** are soils with poorly developed horizons that are associated with steep slopes and erosion-resistant parent material. Inceptisols are located in cool to very warm humid and subhumid regions. They are uncommon in the Southwest thanks to the area's generally dry climate, and are concentrated at high elevations, especially in the Rocky Mountains (*Figure 7.8*).

**Mollisols** are the dominant soils of grasslands. Their thick, black A horizon makes these soils extremely productive and valuable to agriculture. These soils are extensive in the Great Plains, and are also found in bands along parts of the Colorado Plateau (*Figure 7.9*).

**Vertisols** are dark soils, rich in swelling clays. They dramatically change in volume depending on the moisture level of the soil, forming deeply cracked surfaces during dry periods and swelling again in the wet season to seal all the cracks. As a result, they are very difficult soils to build roads or other structures on. Vertisols are rare in the Southwest, and are present only in a few areas of Arizona and New Mexico (*Figure 7.10*).

Although these soil orders occur in other parts of the country, the Southwest's arid climate allows for a secondary way of classifying soils—by the temperature zone in which they occur. Exposure to extreme temperatures means that many Southwestern soils are considered to be **hyperthermic**, and may not seem to have a lot in common with their equivalents in other regions. In addition, many of the area's soils are thin because the requisite conditions for the formation of deep soils are not present.

## Soil Orders

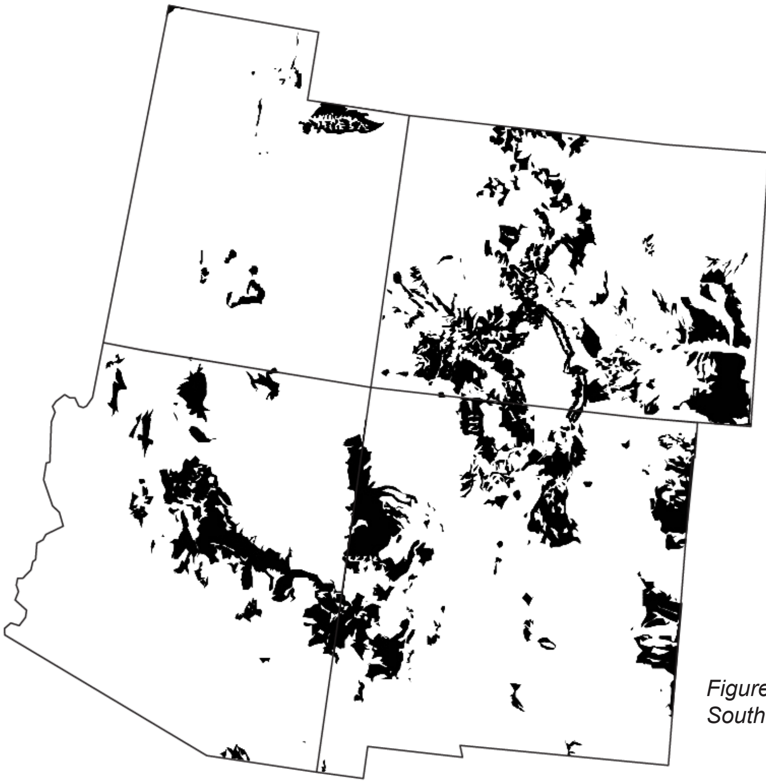


Figure 7.5: Alfisols of the Southwest.

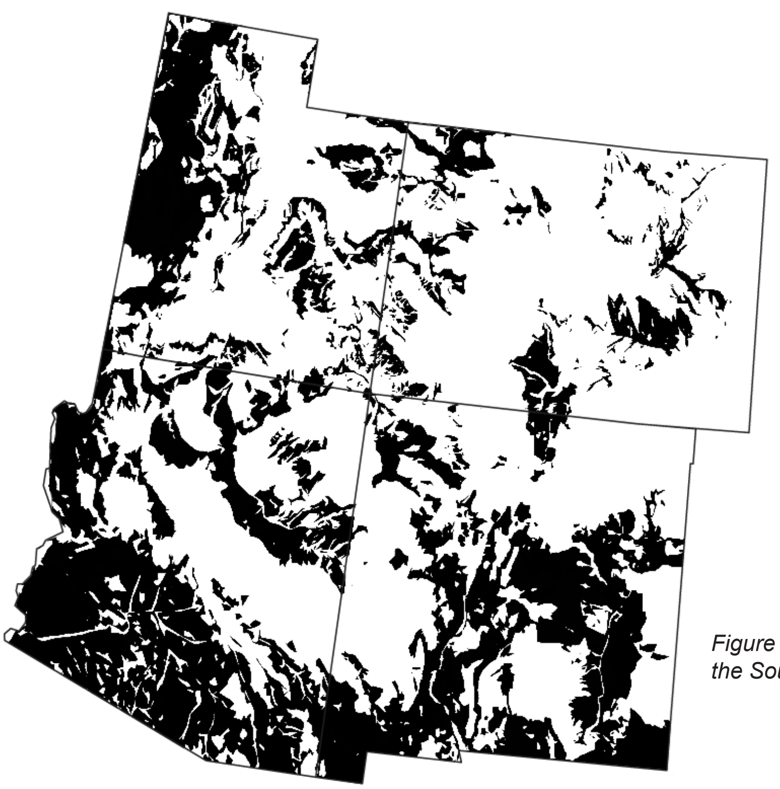


Figure 7.6: Aridisols of the Southwest.

## Soil Orders

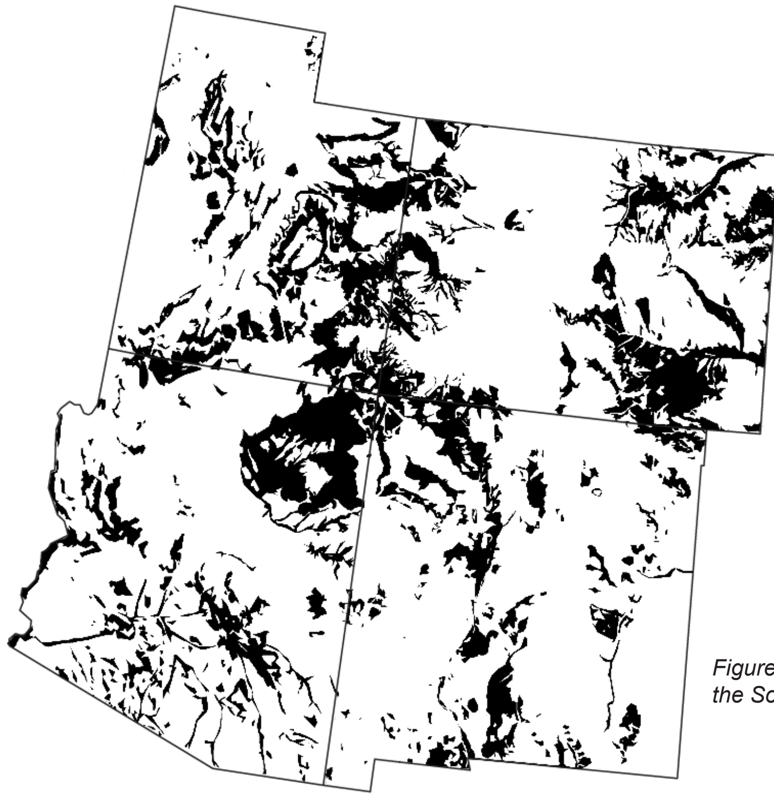


Figure 7.7: Entisols of the Southwest.

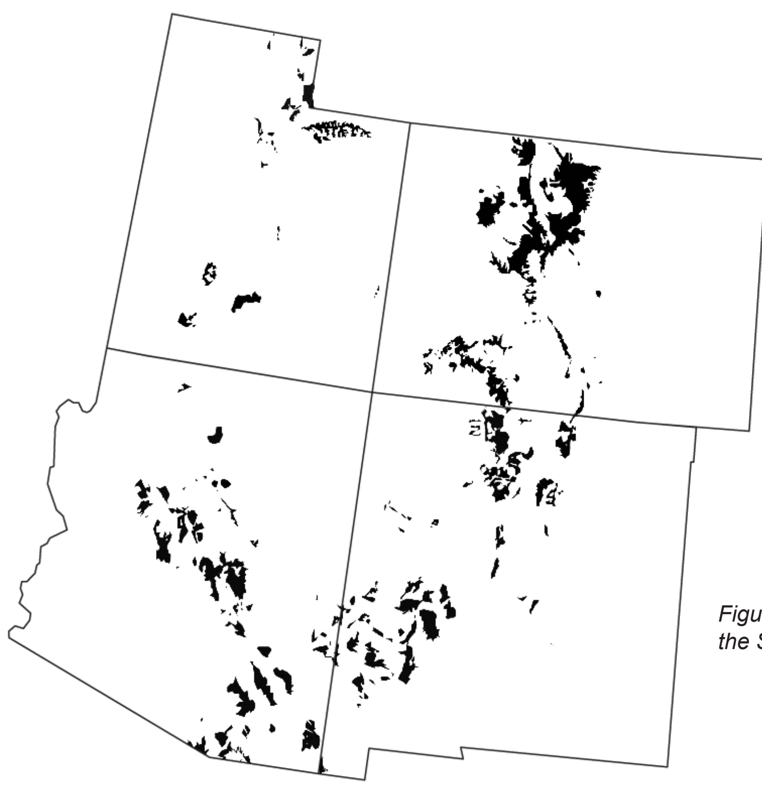


Figure 7.8: Inceptisols of the Southwest.

## Soil Orders

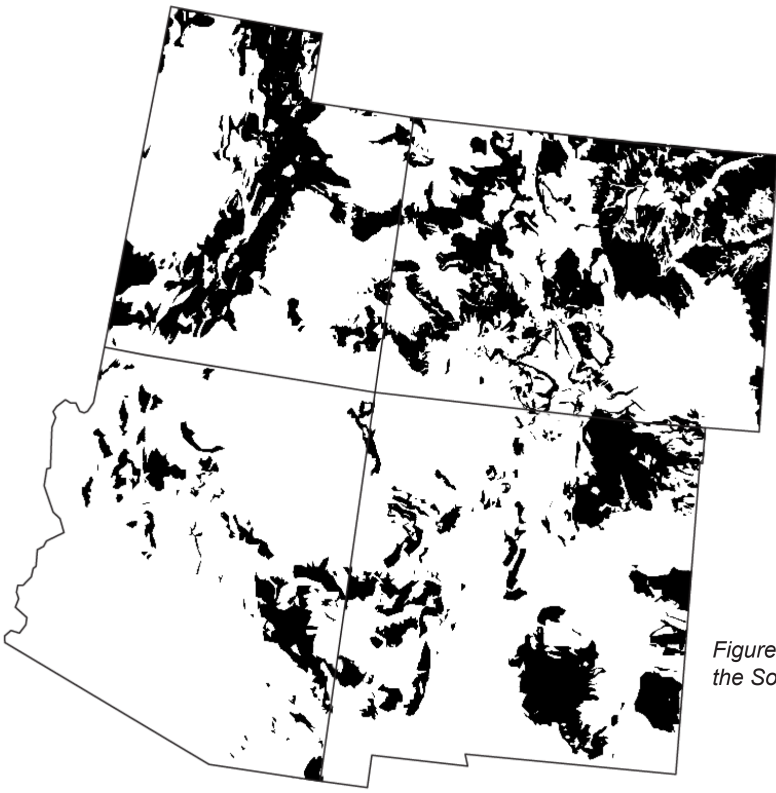


Figure 7.9: Mollisols of the Southwest.

Figure 7.10: Vertisols of the Southwest.

# Soils

## Soil Orders

***hydrography*** *• The science of the physical aspects of water on the surface of the Earth.*

### Geology of the Southwest: Parent Material

The Southwest is home to a wide variety of parent materials—the minerals and organic matter from which its soils are derived (*Figure 7.11*). Mineral material determines a soil's overall fertility and the vegetation it supports.

Weathered sedimentary rock is a ubiquitous parent material throughout many areas of the Southwest. The western half of Utah, for example, is part of a much larger **hydrographic** area known as the Great Basin, which contains **sandstone**, **shale**, and **limestone** that accumulated over millions of years. The eastern halves of Colorado and New Mexico are also home to an abundant supply of weathered sedimentary rock—sandstone, siltstone, limestone, and shale are among the most common bedrocks in this portion of the Southwest. Much of this rock was laid down during the **Paleozoic,** when shallow **inland seas** repeatedly flooded the landscape.

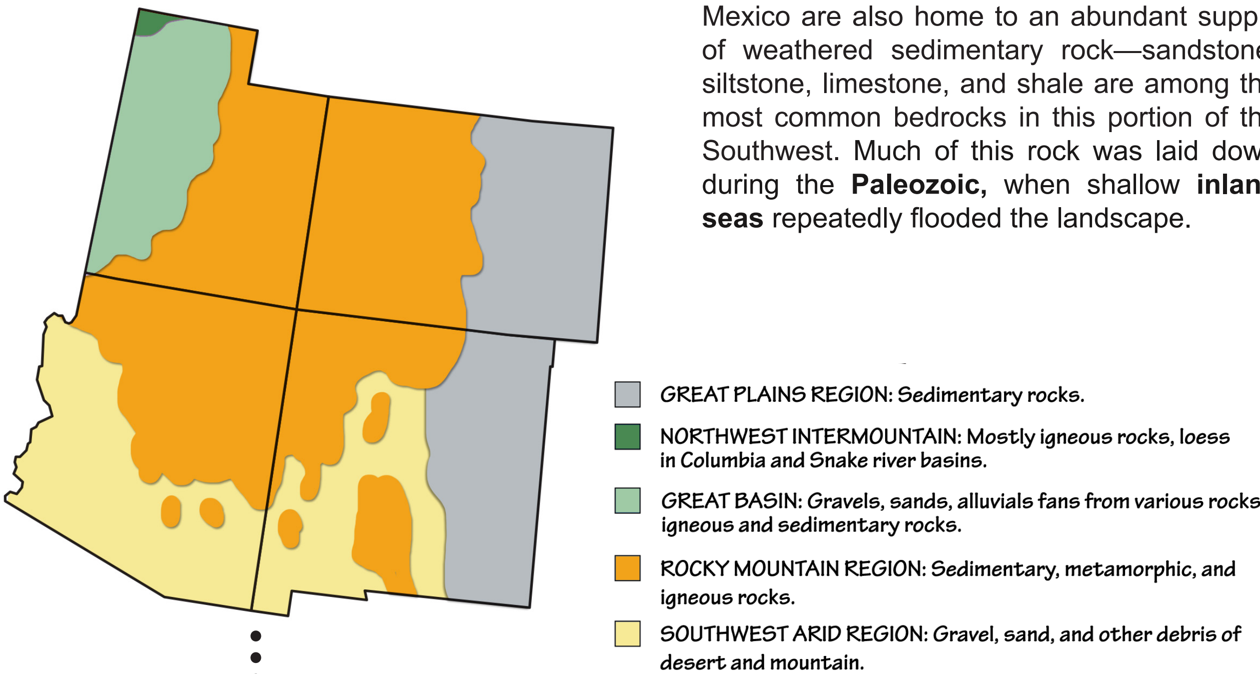



*Figure 7.11: Physiographic and regolith map of the Southwest. (See TFG website for full-color version.)*

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

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

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

The majority of the Southwest contains extremely varied parent material generated during the tectonic events that led to the **uplift** of the Rocky Mountains. **Orogenic** events during the **Mesozoic**, eruptions of ash and **lava** from **volcanic** mountain ranges to the west, and inundation by the late **Cretaceous** Western Interior Seaway all contributed to the formation of the igneous, sedimentary, and metamorphic rock types found throughout the area. Soils in the Rocky Mountain and Colorado Plateau regions are derived largely from the erosion of these materials, while soils in the Basin and Range are mostly composed of **gravel**, sand, and other debris eroded from the desert and mountainous landscape.

## Soils of the Colorado Plateau
### Region 1

The Colorado Plateau is a high region, with an average elevation of 1500 meters (5000 feet). Slopes are relatively gentle across the region, except in mountain ranges, such as the Henry Mountains of Utah, which owe their existence to **magmatic intrusion**. The geology of the Colorado Plateau comprises mostly Mesozoic-aged sedimentary rocks.

**See Chapter 2: Rocks to learn more about mountains formed by magmatic intrusion.**

The most common soils on the Colorado Plateau are Aridisols, which occur in the region's mid-elevations. These dry, coarse soils formed from the weathering of limestones and **carbonate** parent material deposited in ancient seas. Due to a lack of precipitation that would leach out soluble minerals, Aridisols contain high concentrations of **gypsum**, carbonates, and salt, which sometimes solidify into **caliche**—a hard, light-colored layer **cemented** together by **lime**. They support drought-resistant vegetation, especially sagebrush steppe ecosystems (*Figure 7.12*). Irrigation can convert these soils into useable cropland, but they are also managed for livestock grazing.

*Figure 7.12: Aridisol soils support the growth of this sagebrush steppe near Utah's Henry Mountains.*

Region 1

***Paleozoic*** • *a geologic time interval that extends from 541 to 252 million years ago.*

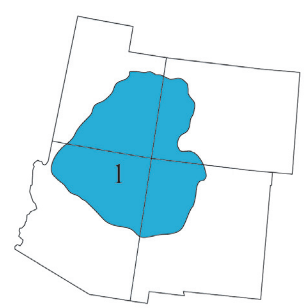
***inland sea*** • *a shallow sea covering the central area of a continent during periods of high sea level.*

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

***orogeny*** • *a mountain-building event generally caused by colliding plates and compression of the edge of the continents.*

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

***lava*** • *molten rock located on the Earth's surface.*



# 7 Soils

## Region 1

***conifer*** *• a woody plant bearing cones that contain its seeds.*

***windward*** *• upwind; facing into the prevailing winds, and thus subject to orographic precipitation.*

Alfisols are relatively uncommon on the Colorado Plateau. These soils generally form in forested areas as a result of weathering processes that leach minerals from the surface layer into a clay-rich subsoil, where nutrients are retained. Many occur beneath **conifer** forests in the region's higher elevations, especially along the Mogollon Rim in Arizona (*Figure 7.13*) and in the Zuni Mountains in western New Mexico, the southern Chuska Mountains in eastern Arizona, and the Henry Mountains in south-central Utah.

**See Chapter 4: Topography to learn about the physiography of the Colorado Plateau.**

*Figure 7.13: Pale-colored, leached Alfisols are exposed on this path in Coconino National Forest, Arizona.*

Mollisols constitute the most fertile soils on the Colorado Plateau, formed where organic matter accumulates beneath prairie grasses and in poorly drained forests (*Figure 7.14*). These soils are rich in humus, which stores mineral nutrients and contributes to the soil's high moisture and nutrient content. In the central parts of the Plateau, they are scattered at mid-elevations on the **windward** sides of mountain ranges where moisture is slightly more abundant. Mollisols are particularly rich in western Colorado, allowing for the cultivation of fruit orchards and other crops. They are also found in a wide band stretching through central Utah along the Plateau's western margin, where they form some of the state's most productive and important agricultural soils.

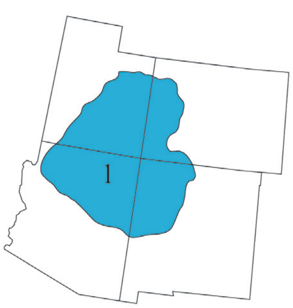
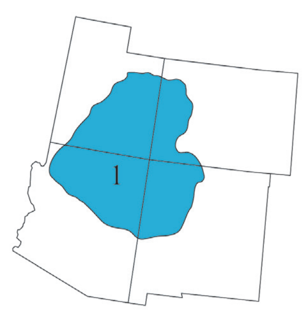


*Figure 7.14: A farm in Paonia, Colorado irrigates this field of rich Mollisols with a system of channels.*

Entisols, young soils lacking in horizons, are found where erosion and deposition occur faster than the rate of soil formation. In the Colorado Plateau they are common on recent erosional surfaces, especially along the Colorado River and other river courses (*Figure 7.15*). They also occur as shallow soils on the bedrock of arid uplands. Inceptisols are rare here; these weakly developed soils can be found scattered throughout the region in mountainous areas and on steep slopes.

*Figure 7.15: An accumulation of sandy Entisols marks a dry riverbed near Palisade, Colorado.*



## Soils of the Basin and Range
### Region 2

The Basin and Range is a unique topographical region consisting mostly of north- and south-running mountain ranges and valleys. These features formed as a result of extension of the continental **crust** during the **Neogene**. This extension, or stretching, caused the crust to break along straight, nearly parallel **faults**, along which steep mountains rose and flat-bottomed valleys dropped. In the Southwest, valley bottoms can be close to sea level, particularly in southwestern Arizona (in Death Valley, California, the Basin and Range actually has valleys below sea level). The mountains, on the other hand, can top 3000 meters (10,000 feet)! The region's low valleys are commonly occupied by dry, alkaline lakes with very little vegetation, but in the slightly cooler, higher valleys of southern Arizona and south-western New Mexico, the soil is more hospitable to plant growth.

**See Chapter 4: Topography for more information about the formation of the Basin and Range.**

With the exception of high mountaintops, a very dry climate dominates the Basin and Range. Aridisols are by far the most common soils, occupying the low- and mid-elevation parts of the basins and adjacent mountain ranges. These soils tend to contain a high amount of calcium carbonate, and are moderately to strongly alkaline; they support drought-resistant plants including sagebrush, Joshua tree, and yucca. While many Aridisols are beyond the practicality of common agricultural and economic practices, not all have been left undeveloped. Many of the region's Aridisols belong to the suborder Argids, which are rich in clay; with irrigation, these can be productive soils (*Figure 7.16*). In northwestern Utah, however, the dominant suborder is Salids—these fine-grained and **salt**-heavy soils are commonly found in depressions and **playa lakes**, including the extensive Great Salt Lake Desert.

*crust* • *the uppermost, rigid outer layer of the Earth.*

*Neogene* • *the geologic time period extending from 23 to 2.6 million years ago.*

*fault* • *a fracture in the Earth's crust in which the rock on one side of the fracture moves measurably in relation to the rock on the other side.*

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

*playa lake* • *ephemeral or dry lakebed that occasionally contains only a thin layer of quickly evaporating water.*

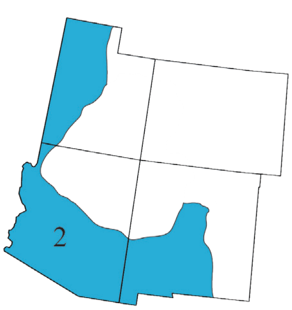



*Figure 7.16: The famous chile pepper farms of southern New Mexico produce their crops in Aridisol soils.*

## Region 2

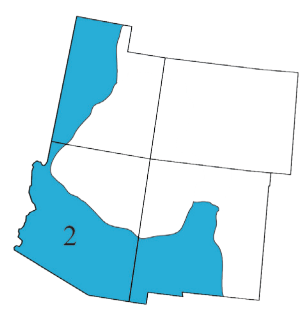
***Pleistocene*** • *a subset of the Quaternary, lasting from 2.5 million to about 11,700 years ago.*

***delta*** • *a typically wedge-shaped deposit formed as sediment is eroded from mountains and transported by streams across lower elevations.*

Entisols are the next most common type of soil in the Basin and Range. These soils, young and lacking in horizons, are found scattered along floodplains and streams where alluvial sediments are deposited, and river valleys where unconsolidated sediment has been transported from the steep surrounding slopes. In Utah, several areas of highly sandy sediment have been designated as dune land. One of the largest dune fields in the state is Little Sahara, whose sand dunes result from silicate-rich deposits left by the Sevier River during the **Pleistocene** (*Figure 7.17*). Strong winds carried the sediment from the river **delta** to its current location, where it covers an area of about 570 square kilometers (270 square miles).

*Figure 7.17: Sand Mountain, a 210- to 245-meter (700- to 800-foot) wall of Entisol sand at Little Sahara in Utah, is a popular location for ATV riding.*

Other soil types that appear in the Basin and Range are uncommon. Soils weathered from the region's mountains are characteristically rocky, shallow, and gravelly. Dry Alfisols occur near the tops of the highest mountains in southern Arizona and New Mexico, and along the Mogollon Rim at the edge of the Colorado Plateau. Freely drained Inceptisols, associated with steep slopes and resistant parent material, occur scattered across mid-elevations in southern Arizona and southwestern New Mexico. 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. Arid Mollisols, which are fertile but can become dusty and dry during drought conditions, are present at mid-elevations that surround mountains where moisture is slightly higher.



# Soils

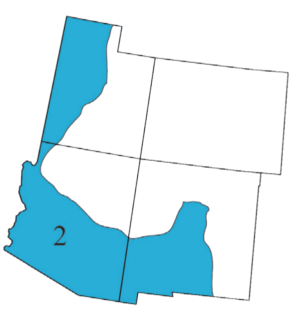
## Region 2

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

In the Basin and Range, patches of soil have been 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. The only Vertisols found in the Southwest occur in the Basin and Range, in southern Arizona and New Mexico (*Figure 7.18*). During dry periods, these clayey soils shrink and form wide cracks at the surface; the cracks seal shut again when moisture enters the soil. Because Vertisols shrink and swell so readily, it is extremely difficult—and even dangerous—to build structures or roads on top of them. Expansion of the clay minerals can cause foundations to crack and roads to buckle; millions of dollars are spent every year on repairing damage done by expansive soils. The action of shrinking and swelling within the soil also prevents the formation of distinct horizons.

**See Chapter 9: Earth Hazards to learn more about the dangers associated with expansive soils.**

*Figure 7.18: Cracked Vertisol soils near Ash Fork, Arizona.*



# Soils of the Rocky Mountains
## Region 3

Region 3

The Rocky Mountains of the Southwest encompass the mountains of central and northwestern Colorado and northeasternmost Utah. The region took form as a result of several orogenic events starting in the Paleozoic, and the present-day Rockies owe their current topography to events that occurred in the **Paleogene**. The Rockies actually consist of many mountain ranges with high-elevation valleys in between. These valleys are higher than the average elevation of the Colorado Plateau, generally reaching heights of around 1700 to more than 2100 meters (5500 to more than 7000 feet). The Rocky Mountains are home to many of the highest peaks in the continental US, with 54 peaks topping 14,000 feet (approximately 4270 meters)! At the highest elevations, bare rock predominates, but soils have formed below the **tree** line.

**See Chapter 4: Topography for more about the highest points in the Southwest.**

Not surprisingly, the soils of the Rocky Mountains are quite different from those found in surrounding areas of the Southwest. The region's higher elevation means that water is more abundant, both because temperatures are cooler, which reduces evaporation, and because rainfall and runoff are higher, particularly on the windward sides of the mountains. For this reason, Aridisols, which are widespread elsewhere in the Southwest, are uncommon in the Rocky Mountains, although clay- and carbonate-rich soils are scattered throughout the mountains of northwestern Colorado and northeastern Utah. Alfisols, in contrast, are common at higher elevations and support forested areas with a short, cool growing season. Entisols are uncommon, but do occur in the region's valleys.

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, and often overlie erosion-resistant bedrock. While Inceptisols represent a level of soil development one step above that of Entisols, they are still very poorly developed. The Rocky Mountains of northern Colorado, especially the Medicine Bow, Front, and Park ranges, host a high concentration of these soils (*Figure 7.19*). The thin, rocky nature of Inceptisol soil prevents significant water retention, placing lower limits on plant cover.

Mollisols are common throughout lower elevations of the Rockies. These loamy soils are well drained and **permeable**, containing ample organic matter and a high nutrient content. Valleys that contain these highly productive dark soils naturally support forest, grass, and shrubland. They are used to raise a variety of crops, including hay, wheat, and barley, and also as rangeland for cattle.

***Paleogene*** • *the geologic time period extending from 66 to 23 million years ago.*

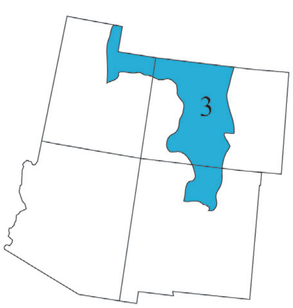
***tree*** • *any woody perennial plant with a central trunk.*

***permeability*** • *a capacity for fluids and gas to move through fractures within a rock, or the spaces between its grains.*

# 7 Soils

Region 3

Figure 7.19: The Nokhu Crags, part of Colorado's Never Summer Mountains, erode to form weathered Inceptisols.



## Region 4

**Cenozoic** • *the geologic time period spanning from 66 million years ago to the present.*

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

# Soils of the Great Plains
## Region 4

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. In the Southwest, this relatively flat region runs along the eastern edge of Colorado and New Mexico. Here, the Great Plains tends to be at a higher elevation than it is farther east; the area of lowest elevation runs through southeastern New Mexico, in the broad valley occupied by the Pecos River. Most of the region's soils are derived from Mesozoic- and **Cenozoic**-aged sedimentary rock that mantles the area.

Mollisols are the most common type of soil in the Great Plains. The region is 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, limiting crop yields and leading to damaging dust storms such as those that occurred during the Dust Bowl of the 1930s. Decreased precipitation and lower soil fertility provides for a localized agricultural economy based heavily in rangeland livestock (*Figure 7.20*), and crops here often require irrigation from local **aquifers** or various surface water impoundments. Despite these limitations, fruits, nuts, vegetables, and wheat are all grown in the Great Plains' Mollisols.

*Figure 7.20: Cows graze in New Mexico rangeland underlain by dusty Mollisols.*

*fossil* • *preserved evidence of ancient life.*

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

*granite* • *a common and widely occurring type of igneous rock.*

*rhyolitic* • *a felsic volcanic rock high in abundance of quartz and feldspar.*

*andesite* • *a fine-grained extrusive volcanic rock, with a silica content intermediate between that of basalt and dacite.*

*quartzite* • *a hard meta-morphic rock that was originally sandstone.*

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

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

Entisols are also common throughout the Great Plains, especially at lower elevations and along river courses where they are generated by slope erosion. Sandy deposits of wet Entisols can be found all along the tributaries and banks of Colorado's Platte River, and the Pecos River in New Mexico frequently deposits alluvial materials on its floodplains. Layers of sandy soil in the northeastern part of Colorado provide a productive foundation for rangeland and pasture.

Alfisols occur mostly in the high-elevation areas of the Great Plains, especially in southeastern Colorado, where open forests of juniper and other conifers grow.

## 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.

### Arizona

The state soil of Arizona is the Casa Grande series, an Aridisol. This soil is known to cover roughly 110,000 **hectares** (275,000 acres) but may actually cover nearly one million hectares (several million acres) of the state. This dry soil series forms in alluvium derived from weathered and eroded **granite**, **rhyolite**, **andesite**, **quartzite**, limestone, and **basalt**. With irrigation, these soils become productive and are used to raise vegetables, grain, and cotton.

### Colorado

The Seitz series is a group of Alfisols that cover approximately 140,000 hectares (350,000 acres) of primarily mountainous terrain throughout southwestern and central Colorado. These soils support spruce and fir populations at higher altitudes, and are also home to an understory of grasses, forbs, and shrubs.

### New Mexico

In New Mexico, Aridisols called Penistaja soils cover more than 400,000 hectares (one million acres). Named for a Navajo word meaning "forced to sit," Penistaja soils are formed in mixed alluvium and **aeolian** material derived from sandstone and shale. They support productive rangeland and are commonly used to graze livestock.

### Utah

Covering more than 80,000 hectares (200,000 acres) of southeastern Utah, Mivida soils form in warm, semiarid climates. These coarse and loamy Aridisols are home to many unique plants, including Wyoming big sagebrush, Indian ricegrass, galleta, and blue grama.

# Resources

## General Books and Articles on Soils

Lindbo, D. L. and J. Mannes, 2008, *Soil!: Get the Inside Scoop*, Soil Science Society of America, Madison, WI, 32 pp.
Lindbo, D. L., 2012, *Know Soil, Know Life*, Soil Science Society of America, Madison, WI, 206 pp.
Logan, W. B., 1995, *Dirt: the Ecstatic Skin of the Earth*, Riverhead Books, New York, 202 pp.
O'Meara, C., 2013, Do you know dirt about soil? Here's a three-step primer, *Denver Post*, March 27, 2013, http://www.denverpost.com/2013/03/27/do-you-know-dirt-about-soil-heres-a-three-step-primer/.
Soil Survey Staff, 2014, *Keys to Soil Taxonomy, 12th edition*, US Department of Agriculture, Natural Resources Conservation Service, Washington, DC, 362 pp., http://www.nrcs.usda.gov/ wps/PA_NRCSConsumption/download?cid=stelprdb1252094&ext=pdf.
Soil Survey Staff, 2014, Illustrated Guide To Soil Taxonomy, US Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE, 498 pp., http://www. nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1247203&ext=pdf.

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

## Books and Websites on Soils of Specific Parts of the Southwest

Boettinger, J. L., 2009, *Soils of Utah*, Soil STATSGO2 Soil Database, US Department of Agriculture, pp. 46–48, http://extension.usu.edu/utahrangelands/files/uploads/RRU_Section_Six.pdf.
Hendricks, D. M., ed., 1986, *Arizona Soils*, College of Agriculture, University of Arizona, Tucson, AZ, 244 pp., http://www.library.arizona.edu/exhibits/swetc/azso/.

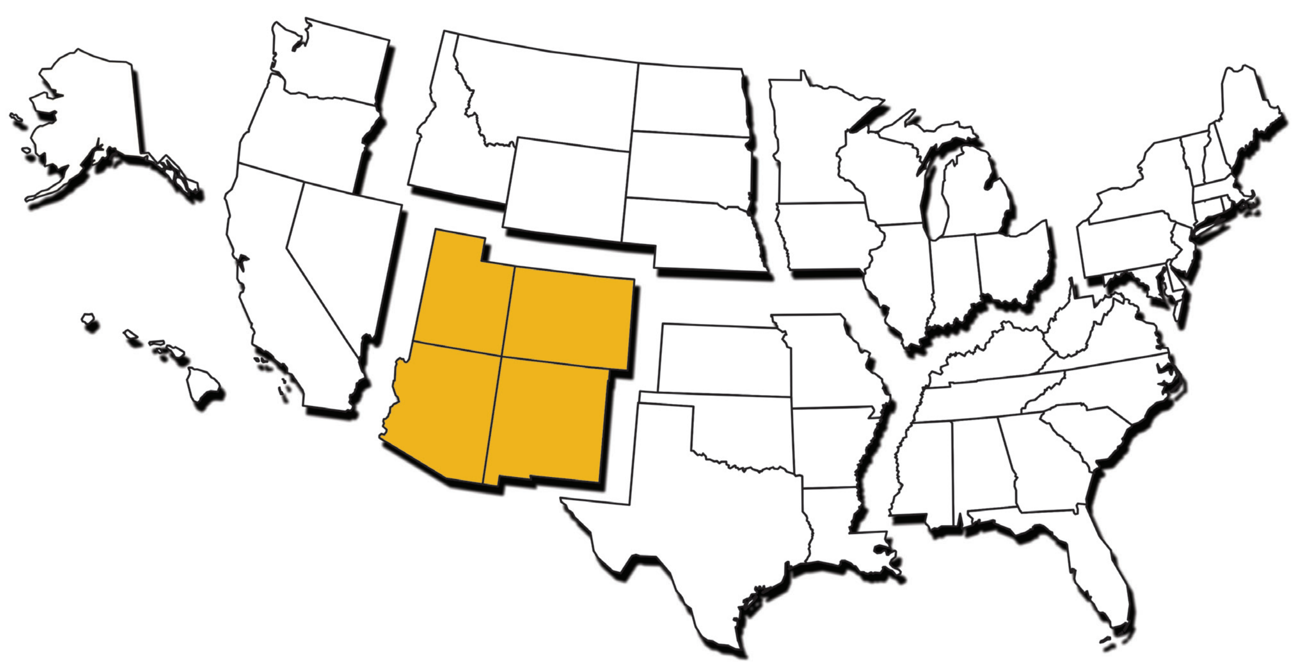
The

# Teacher-Friendly

Guide™

to the Earth Science of the

# Southwestern US



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**On the back cover:** Blended geologic and digital elevation map of the Southwestern 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.