KANSAS MASTER NATURALIST PROGRAM

Geology & Soils

Permian red beds in Clark County. Image courtesy of the Kansas Geological Survey.

Chapter Goals

- Describe the components of soil
- Describe the soil horizons/layers
- Discuss the physical properties
- Describe the causes of soil erosion and prevention practices
- Become aware of and understand the basic processes that form rocks
- Describe various landforms regions in Kansas
- Describe the physical and chemical properties of soil in Kansas
- Discuss ways to prevent soil erosion

A. Introduction to Geology

Geology can be defined as "the origin, history, and structure of the earth". For the purposes of the Kansas Master Naturalists, we will only be interested in a basic understanding of geology, the effects of geology on the landscape, and on the habitats created by geologic processes. The more we study and learn about geology, it will become apparent that the geology of a region is responsible for many of the ecological processes that influence the formation of habitat.

B. Geologic History of Kansas

The age of the earth is estimated to be at least 4.5 billion years. Over the 4.5 billion year span, mountains have been raised and eroded, then raised again. Seas have spread over the land; layers of sand, mud, and calcium carbonate have been deposited on the sea floors, and the waters have retreated, leaving layers of rock thousands of feet thick. Volcanoes have erupted, just as they are doing in many places today, and left large areas of lava behind. Volcanic dust or "ash" has settled to the earth, sometimes in lakes or ponds, burying whatever lay beneath. Glaciers, formed during long cold periods, and have covered a large part of North America, but have melted back as the climate warmed.

All these events have taken place during the **geologic history** of the earth. The 4.5 billion years of earth history have been divided into large units of time called **eras**. Eras have been divided into smaller units called **periods** and these in turn have been divided into **epochs**.

Era
Periods
Epochs

Kansas Geologic Timetable

(Not scaled for geologic time or thickness of deposits)

Eras	Periods	Epochs	Est. length (Years) *	Description	Million Years Past
CENOZOIC	QUATERNARY	HOLOCENE 	10,000+	Early, the land was stable with some erosion. Glaciers moved into the northeast at least twice. Later the climate was dry. Sand dunes were formed by wind in the west. Volcanic ash was blown in from California, New Mexico, and Wyoming.	
		PLEISTOCENE	1,790,000		1.8
	TERTIARY	PLIOCENE 	3,500,000	Western third of the state covered by terrestrial (nonmarine) sand and gravel deposits which contain large quantities of ground water. No rocks formed in eastern Kansas.	
		MIOCENE	18,500,000		
		OLIGOCENE	9,900,000		
		EOCENE	21,100,000		
		PALEOCENE	10,200,000		65
MESOZOIC	CRETACEOUS		77,000,000	Much of the western half was covered by seas. Limestone, sandstone, and chalk formed from sea deposits. Fossils can be found in these rocks, which crop out in central and western Kansas.	142
	JURASSIC		63,700,000	Western one-fifth of the state; subsurface only. Terrestrial (nonmarine) deposits mainly shale and sandstone.	205.7
	TRIASSIC		42,500,000	Only extreme southwestern part of the state, mostly in subsurface. A few small outcrops. Red sandstones and conglomerates	248.2
PALEOZOIC	PERMIAN		41,800,000	Seas rose and fell across much of Kansas depositing the limestone, shale, and chert that form the Flint Hills. Later, shale, siltstone, sandstone, dolomite, salt, and gypsum--rocks that form the Red Hills--were deposited. Salt now is mined in central Kansas.	290
	PENNSYLVANIAN		33,000,000	Seas rose and fell across much of Kansas depositing shale, limestone, sandstone, chert, conglomerates, and coal; coal formed in swamps from dead plants. Two ridges of hills, the Nemaha uplift and the Central Kansas uplift, appeared; both now are buried. Pennsylvanian rocks are found at the surface in eastern Kansas.	323
	MISSISSIPPIAN		31,000,000	Repeated layers of limestone, shale, and sandstone indicate that seas rose and fell. Mississippian rocks are the oldest found at the surface and are in the southeast corner; elsewhere these rocks are underground only.	354
	DEVONIAN		63,000,000	Seas covered Kansas during much of the period. Limestone, shale, and sandstone deposits are underground only.	417
	SILURIAN		26,000,000	Land was uplifted and seas disappeared. Limestone deposits are found underground only.	443
	ORDOVICIAN		52,000,000	Seas covered parts of Kansas during much of the period. Dolomite and sandstone are only underground.	495
	CAMBRIAN		50,000,000	Early, the climate was dry and many rocks eroded. Later, parts of Kansas were covered by seas. Dolomite, sandstone, limestone, and shale are underground now.	545
PRECAMBRIAN			4,055,000,000	These rocks are the oldest on earth. In Kansas, they are found deep below the surface and little is known about them. Many are igneous and metamorphic rocks that have gone through many changes.	4,600?

*REFERENCES: A Phanerzoic Time Scale, 1996, by F. M. Gradstein and J. G. Ogg, Episodes, v. 19, nos. 1, 2
A Revised Cenozoic Geochronology and Chronostratigraphy, 1995, by W. A. Berggren, D. V. Kent, C. C. Swisher, III, and M.-P. Aubry, SEPM (Society for Sedimentary Geology) Special Publication No. 54

Eons not shown
Kansas Geological Survey, 1999

The layers of rock beneath the earth's surface also are situated into segments. A **formation** is the fundamental rock unit used in mapping, and consists of a uniform rock type that can be distinguished from adjacent, underlying or overlying rock units at sight. Two or more formations that are in some way related, such as in origin or location may be called groups.

Formations are always named from some geographical feature--a town, a river, a mountain--in the region where the particular rock units are well exposed. Thus the Wellington Formation, deposited during the Permian Period of the Paleozoic Era, was so named because it is well exposed in the region around Wellington, Kansas.

Rock Deposition

In general it can be said that the oldest rocks, which were deposited first, lie below the younger rocks that were laid down later. Consequently, on geologic timetables it is customary to put the oldest rocks at the bottom and the youngest rocks at the top.

Paleozoic Era

Mississippian Period: Much of the early history of Kansas geology is known only from samples collected during the drilling of wells. This is true of all periods up to the Mississippian, the oldest period with rocks exposed at the surface, in the southeast corner of Kansas. Subsurface samples have shown that during the early Paleozoic, Kansas was undergoing alternate depression and elevation of land. When the land was lowered the sea advanced, but when the land was raised the sea retreated and erosion set in. These conditions lasted through the Mississippian Period.

Pennsylvanian Period: During the Pennsylvanian Period, the land was flat and near the sea level. The deposits of the period are unusual in that they show a regular alternation of marine deposits (limestones and shales) with non-marine deposits (shales, sandstones, and coals). There are many fossils in the deposits, and some of the limestones consist almost entirely of the shells of sea animals. Pennsylvanian coal deposits are common. The coal was formed from the remains of plants that lived in swamps; these plant remains were buried by later deposits as the sea came over the region, and were converted into coal during compaction of the sediment. This coal has been mined throughout eastern Kansas, from small pits near Topeka to large, open-pit strip mines near Pittsburg. Good exposures of Pennsylvanian rocks showing alternations of shale and limestone exist in many places in eastern Kansas.

Permian Period: The early part of the next period, the Permian, was very much like the Pennsylvanian, although during most of this time the sea covered the region, and little coal was formed. Sometime during the Permian, however, the sea water began to change in composition. Because sea water contains large quantities of dissolved salts such as calcium carbonate,

calcium sulfate, and sodium chloride in solution, a residue of salts is left behind when the sea water evaporates. The Permian sea in Kansas apparently became partly separated from the main body of the ocean, and the water in this sea left layers of sodium chloride (which we call simply salt) and calcium sulfate (gypsum and anhydrite) many feet thick. There must have been a supply of water coming into this inland sea from the ocean in order to provide enough salt to form deposits so thick. These thick salt deposits are mined in central Kansas, notably near Hutchinson. At times the sea was drained, and the sand and silt were deposited over the salt, gypsum, and shale; these interesting Permian deposits include the red beds of south-central Kansas. The sand and silt were washed down from the distant mountains and deposited along the shores of the retreating Permian sea. The red beds have some gypsum, salt, and dolomite inter-bedded with them.

Mesozoic Era

Following the Permian Period, there was a long interval of non-deposition and erosion in Kansas. There may be some Triassic rocks in Morton County, but the age of these has not been definitely determined. Jurassic rocks are present in the subsurface of the western part of the state.

Cretaceous Period: The next rocks laid down in Kansas are those of Cretaceous age. The sea again came over the region, this time leaving a succession of sands, muds, and chalks, alternating with coastal stream, swamp, and beach deposits. The well-known chalk of Kansas is of Late Cretaceous age. Another famous Cretaceous deposit of Kansas and adjoining states is the Dakota Formation, which is frequently called sandstone because the most prominent beds--those that cap the hills and stand out as cliff formers--are sandstones. These sandstone layers are the source of water in many wells in the central and western part of the state. About 80 percent of the Dakota Formation, however, consists of clays of many colors. Also, the formation contains beds of lignite, which, though not a high-grade fuel, was used by the early pioneers for heating their homes and for other purposes.

Exceptionally good fossil specimens found in the upper Cretaceous beds have made Kansas rocks world famous among the fossil experts. These fossils include fishes (fig. 21), bat-like flying reptiles, the sea serpents called mosasaurs, and toothed swimming birds.

Cenozoic Era:

After the close of Cretaceous time, the surface of Kansas was uplifted and subjected to prolonged erosion. The Rocky Mountains were formed by deformation of the earth's crust that occurred at intervals from late in Cretaceous time until well into Tertiary time. The deposits next younger than Cretaceous that are found in Kansas are the late Tertiary sands and gravels of the Ogallala Formation. The Rocky Mountains were being worn

down by the action of water and wind, and the sands and gravels were carried eastward by the rivers, which, being overloaded with sediment, dropped their excess sand and gravel along the river valleys. Gradually the valleys were filled with these sediments, and finally the hills themselves were covered. In some places there were lakes in which freshwater limestones were deposited. Before deposition stopped, a broad, gently sloping plain had been formed. The existing remnants of this plain extend from Colorado east through Dakota southward into Texas. Today this entire area is called the High Plains.

Quaternary Period: When deposition of sand and gravel in what is now the High Plains area stopped, there was a long period of stability, followed by another interval of erosion before the glaciers of the Ice Age or Pleistocene Epoch invaded Kansas in the Quaternary Period. The glaciers advanced and receded at least four principal times.

Only the northeastern part of Kansas was covered by glaciers. Consequently, the rocks carried by the glaciers and dropped as the ice melted are found only in that part of the state. On the outskirts of this glaciated area are many river gravels containing pebbles and boulders washed out of the glacier by the streams of water from the melting ice. The many rust-colored or pink boulders seen in the northeastern part of the state were carried here from north of Kansas by the glaciers, and left when the ice receded. A windblown dust called loess was deposited around the edges of the glacier area, on the High Plains surface and in the valleys of western Kansas far from the ice sheet. River gravels and dust from later ice advances that did not extend as far south as Kansas were deposited both on top of the glacial boulder clay and on the earlier loess.

Today: Many geologists class the time in which we are now living as part of the Pleistocene Epoch because the climate and nature of sedimentary deposits closely resemble those that prevailed between advances of the glaciers.

The time since the melting of the last ice sheet from the northern part of the United States is probably less than 25,000 years. During this time in Kansas there has been more erosion of the land surface than deposition, as the main geologic forces that are active today in this region are those which are wearing away the older rocks.

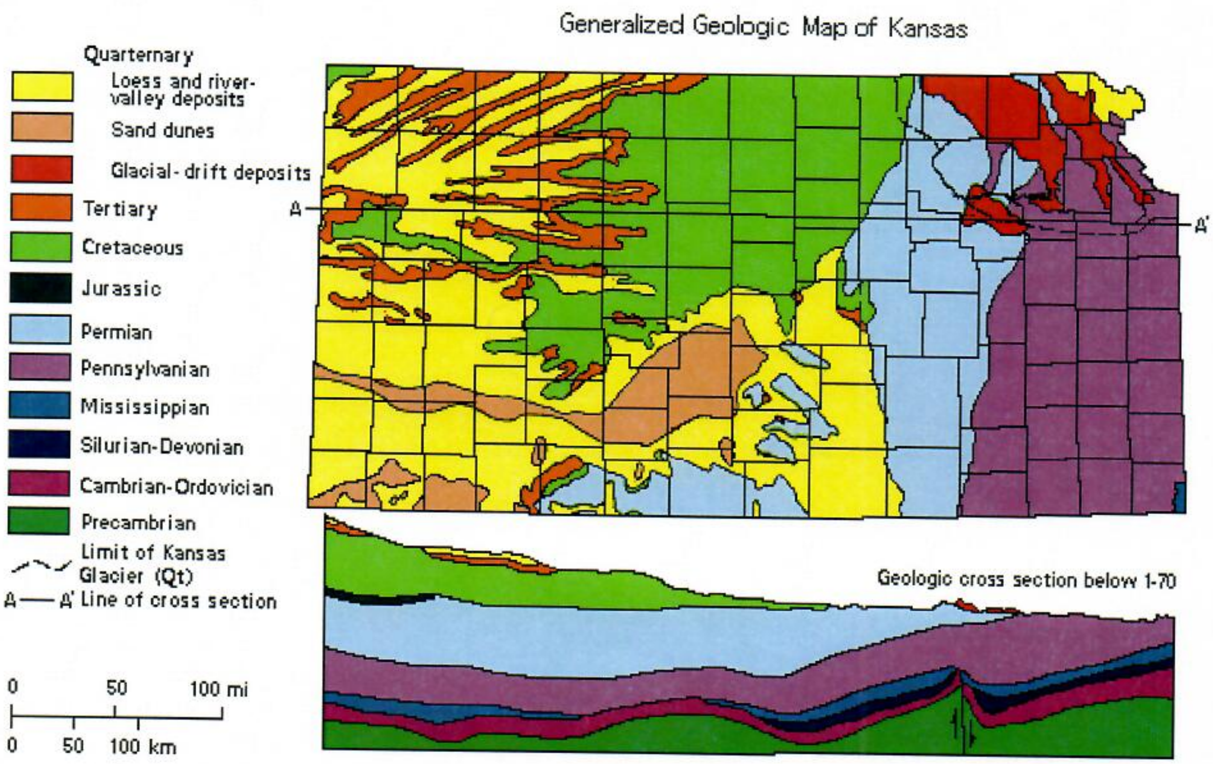
The geologic history of Kansas, then, is largely an alternation of more or less prolonged times of sedimentary deposition and times of erosion during which various volumes of previously formed rocks were destroyed. What effect did this succession of geologic events have on the surface of Kansas as we know it today?

The rock layers have been tilted slightly and eroded, so that some of the older rocks can be seen at the surface. The accompanying geologic map of Kansas and the cross section from

the western to the eastern border of Kansas show how the gentle deformation has caused rocks of different ages to crop out in different parts of the state.

The older rocks, those of Cretaceous age and earlier, have been tilted and the younger rocks have been eroded or worn from above them. Now the Cretaceous and older rocks are exposed in areas that have the form of broad strips with irregular margins. The older rocks (Mississippian and Pennsylvanian) occur in the eastern quarter of Kansas; the rocks of Permian age--next younger than Pennsylvanian--crop out in a north-south belt across central Kansas, and the Cretaceous and Tertiary rocks are found farther west.

The indentations made by valleys that have been cut into the rocks make the pattern of the outcrops irregular. In the northeastern corner of the state, evidence of the southern limit of the glaciers may be seen. Most of the Pleistocene deposits are not shown on the map or cross section because they are so widespread, forming a thin cover over most of the older rocks. If they were indicated, very little else would show.



C. Rock types

A rock is any naturally occurring mass that forms part of the earth's crust. It may consist of sediments and particles (clay, sand, gravel, etc.) as well as solid material (limestone, granite, sandstone). It is normally composed of several minerals. There are three main rocks groups: **igneous, sedimentary** and **metamorphic**.

1. The word **Igneous** comes from the Latin word *ignis* meaning fire. Igneous rock is formed by the cooling and hardening of molten materials. The molten material can harden either above the ground or very slowly beneath the earth's surface. If igneous rock cools slowly beneath the surface, crystals can be large and coarse. Those that cool more rapidly above ground have small, fine crystals.
2. **Sedimentary** rock is formed by the wearing away of other rock material into small particles (sediment). This sediment is deposited and then rock is formed either by cementation or by other processes acting at ordinary temperatures at or near Earth's surface.
3. **Metamorphic** rock, named from the Greeks words *meta* meaning change and *morphe* meaning form; hence: change form. Metamorphic rock is formed within Earth's crust by the transformation of pre-existing igneous or sedimentary rocks as a result of high heat, high pressure or both.

1. Igneous Rocks

Igneous rocks are formed when a hot liquid, called magma, cools and changes from a liquid state to a solid state. They may form slowly underground or rapidly at the Earth's surface. When magma reaches the surface, it is called lava. Lava flows out of a volcano and quickly hardens after an eruption. Although most lava reaches the surface through volcanoes, it may also flow out of deep cracks in the earth without building a mountain.

Kansas doesn't have an active volcano, but lava did flow onto the surface as recently as 90 million years ago when dinosaurs still roamed the Earth. Hot magma forced its way up from over 100 miles below the Earth's surface in two small areas of eastern Kansas. The hot liquid, which spread upward through cracks in other underground rocks, cooled and hardened, forming a rock called lamproite in Woodson and Wilson counties and one called kimberlite in Riley County.

In one area of Riley County, lava flowed onto the surface but a volcanic cone was never formed. The kimberlite formed from the lava is now buried. Lamproite and kimberlite found at the surface in Kansas were exposed when the rock above was eroded away. Diamonds have been found in kimberlites and lamproites in other parts of the world, but none has been found yet in Kansas.

Granite, another type of igneous rock, has been found mixed with lamproite in Woodson County. It is older than the surrounding surface rocks and was formed deep in the Earth. Lamproite magma carried it toward the surface, where it is now exposed.

Some igneous and metamorphic rocks have traveled into Kansas from other places. Volcanic ash, basalt, granite, and quartzite have been carried in by wind, glaciers, and water.

2. Sedimentary Rocks

Sedimentary rock is the most common rock found at surface level throughout the state of Kansas. They may be formed from other rocks that were worn down by erosion into small pieces, such as sand and gravel, called sediment. A solid rock may be formed if the sediment is covered by great thicknesses of other sediment and rocks and pressed together, or if it is cemented together by minerals.

Organic material, which is anything that was once alive, may also be pressed together into a solid mass. Fossils of shells and tiny microscopic plants and animals, left behind when ancient seas dried up, are found in much of the Kansas chalk and limestone. Other common sedimentary rocks in Kansas are clay, shale, bentonite, silt, siltstone, sand, sandstone, dolomite, salt, and coal.

a. Clay, Shale, and Bentonite

Clay is composed of very fine particles eroded from rocks and minerals. These particles are so finely worn that they can only be seen with a microscope. Clays may be a variety of colors-white, gray, black, red, yellow, tan, or green-and are often mixed with larger particles of other sediment such as sand and pebbles. Bricks, dishes, and other ceramic products are made from clay, which is molded and then hardened by heat.

When clay and silt are compacted into a solid rock, it is called shale. Shale erodes easily into clay when exposed in outcrops and road cuts. Like clay, shale can be many different colors and is common in Kansas and throughout the world. It is used to make bricks and as an ingredient in cement.

Bentonite is a type of clay formed from altered volcanic ash. Most types of bentonite swell when they absorb water. Deposits of bentonite have been found in several locations in western Kansas.

b. Silt and Siltstone

Silt consists of particles larger than clay particles but smaller than sand particles. It is deposited by wind and water. Loess (pronounced lus) is a windblown silt found in many areas of Kansas. Thick loess deposits occur in northeast Kansas where rocks and gravel were ground down by glaciers and water. Later the dried mud was

picked up by the wind. Much of it settled near the margins of the glaciers. But loess also covers much of the surface in western Kansas where it was spread around by ferocious dust storms.

When silt is compacted and cemented together, it forms a rock called siltstone, which is found in eastern Kansas.

c. Sand and Sandstone

Sand particles vary in size and can easily be seen without a microscope. Sand often contains eroded particles of rocks and minerals carried downstream by rivers and creeks. Two minerals, quartz and feldspar, are commonly found in sand.

Sand deposits are widespread in the state, especially along streams and river valleys and in old river deposits. Sand hills also cover large areas of south-central and southwest Kansas.

When sand is cemented together, it is called sandstone. Sandstones in Kansas range in color from a light tan to brown to reddish-orange to bright orange. The different colors are caused by a variety of minerals and impurities. Sandstone deposits are found throughout Kansas, and buildings made of sandstone blocks can be found in areas where it is most abundant.

d. Limestone

Limestones are common in Kansas. They are usually found where seas once covered the land. They also can be formed from deposits in freshwater or on dry land, but non-marine limestones are less common.

Most of them were formed from accumulations of marine plants and animals after they died and sank to the sea floor. If conditions were right, millions of tons of plant and animal debris were deposited and eventually compacted together. When the sea dried up, large slabs of rock were formed, often stretching for hundreds of miles in every direction. Some plant and animal remains, such as shark's teeth and dinosaur bones, have been preserved as fossils in limestone.

Sea or freshwater shells, plants, or animals such as algae, corals, clams, oysters, brachiopods, bryozoans, fusulinids, and crinoids are sources of calcite, which is the main mineral found in limestone. Thick deposits of these plants and animals form limestone.

Limestones containing only one mineral--calcite--are white. But most limestones contain other minerals, for example iron oxide (rust), and organic remains. These cause limestone to vary in color, especially when the rocks are exposed to weathering elements such as air and water. Limestones in outcrops and road cuts are usually off-white, tan, or yellow, and may be streaked with other colors.

Some buildings are made of limestone. Crushed limestone also is used to surface roads and is an ingredient in cement. Limestones are found at the surface in many parts of eastern Kansas but are not as common in central and western Kansas. However, chalk, which is a type of limestone, is found in some central and western areas.

e. Chalk

Chalk is a type of limestone often formed from the shells of small, single-celled animals called foraminifera. Pure chalk is fairly soft and white, but it usually has impurities that cause it to be different colors. Many fossils have been found in the chalk beds of western Kansas, among the most extensive chalk beds in the world.

f. Dolomite

Dolomite is similar to limestone; however, it is composed chiefly of a mineral also named dolomite, rather than calcite. Calcite and dolomite are often found together. The rock they form may be called dolomitic limestone or dolomite, depending on the quantities of calcite and dolomite it contains. Dolomite, which is found in some areas of southern and central Kansas, has many of the same uses as limestone.

G. Coal

When plants die in a swamp, their decaying remains are buried in mud. As they become buried deeper in the Earth, the decaying plants are pressed together and heated, forming a firm, brittle rock called coal. Coal can be burned to produce heat or to generate electricity. Before they had electricity, people often heated their homes and other buildings by burning coal. Early steam engines were fired by coal, but today trains run on diesel oil.

3. Metamorphic Rocks

Rocks that have been changed from one kind of rock to another by heat and pressure are called metamorphic, which is Latin for "changed form." Limestone changes to marble; shale to slate, schist, and gneiss; and sandstone to quartzite. Marble, slate, and quartzite are much harder rocks than limestone, shale, and sandstone. Metamorphic rocks are rare in Kansas. Quartzite, which is found in a small area in Woodson County, is the only native metamorphic rock found at the surface. Quartzite boulders can be found throughout northeastern Kansas, but they were not formed there. Glaciers carried the rocks in from South Dakota, Iowa, and Minnesota. They are red, brownish red, or purple.

D. Physiographic Regions of Kansas

Kansas Geological Survey (April 1999)

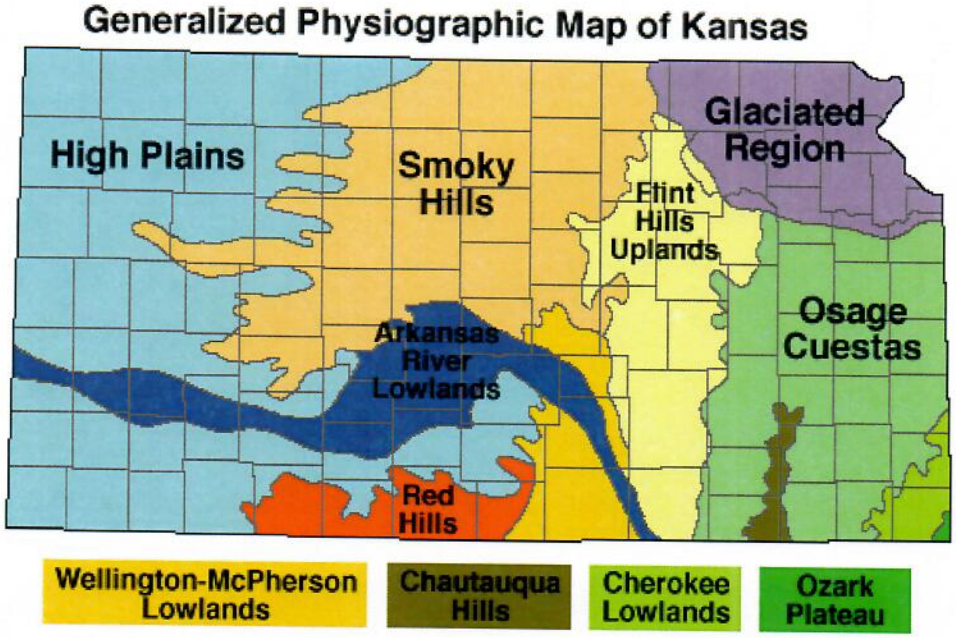


Image courtesy of Kansas Geological Survey

1. Chautauqua Hills

Outcrop of typical Chautauqua Hills sandstone at The Hollow, a city park in Sedan, Kansas. This sandstone is part of the Ireland Sandstone Member of the Lawrence Formation. *Image courtesy of Kansas Geological Survey.*

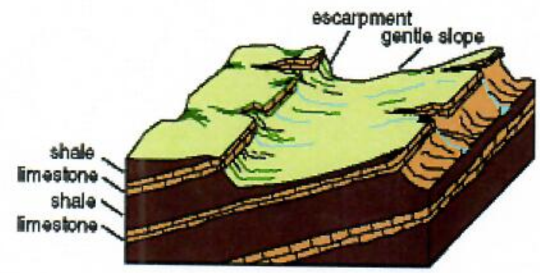
The Chautauqua Hills are a sandstone-capped rolling upland that extends into the Osage Cuestas from the southern Kansas border. Approximately 10 miles wide, these hills extend as far north as Yates Center in Woodson County. Small patches of similar terrain can be found as far north as Leavenworth County. The Chautauqua Hills formed primarily in the thick sandstones of the Douglas Group. During the Pennsylvanian Period, about 286 million to 320 million years ago, rivers and streams flowed into the sea in this area. Sand and other sediments collected in the estuaries and at the mouths of the rivers in deltas. When the seas dried up, the sediments were buried and compacted—the sands became sandstone and the muds became shale. Over millions of years, uplift and erosion exposed the sandstone and shale at the earth's surface. Further erosion has dissected the area into a series of low hills, capped by more resistant sandstone.

Because of rock outcrops in this region, the hills are generally not cultivated but are used instead for pasture. The Verdigris, Fall, and Elk rivers cross the area in narrow valleys walled by sandstone bluffs. Topographic relief in the region is never more than 250 feet. Many of the hills are covered by stands of black jack oaks, scrub oaks, and other hardwood species. This mix of medium-tall grasslands and scattered stands of deciduous trees is called the Cross Timbers by scientists who map vegetation.

2. Cherokee Lowlands

Occupying roughly 1,000 square miles in Bourbon, Crawford, Cherokee, and Labette counties, the Cherokee Lowlands is a gently rolling plain that developed on easily eroded shales and sandstones of the Cherokee Group. Next to the Mississippian outcrops in the Ozark Plateau, the rocks of the Cherokee Group are the oldest rocks occurring at the surface in Kansas. They were deposited during the early part of the Pennsylvanian Period, approximately 300 million years ago.

The gently sloping landscape is traversed by shallow stream valleys. Isolated sandstone hills offer occasional topographic relief. One of these, Blue Mound, is located just east of Kansas Highway 69 in southern Cherokee County, a half mile north of the Oklahoma border. The region is characterized by deep, fertile soils, which have eroded from the soft rocks of the Cherokee Group. These soils and the relatively flat and well-drained topography make the region good for farming, except where the surface has been disturbed by mining. Generally trees grow only on the slopes of hills, banks of larger streams, and in abandoned mining areas.



Cuesta topography developed in gently dipping, alternating layers of hard and soft rocks. *Image courtesy of Kansas Geological Survey.*

3. Osage Cuestas

The Osage Cuestas region occupies nearly all of eastern Kansas south of the Kansas River and is characterized by a series of east-facing ridges (or escarpments), between which are flat to gently rolling plains. *Cuesta,* Spanish for hill or cliff, is the term geologists use to describe ridges with steep, cliff-like faces on one side and gentle slopes on the other.

In the Osage Cuestas, the underlying strata are Pennsylvanianage limestones and shales that dip gently to the west and northwest. Each cuesta consists of a striking east-facing ridge or escarpment and a gently inclined surface that slopes in the direction of the dip of the strata. Each escarpment is capped by the more-resistant limestone, while the gentle slopes are underlain by thick layers of shale. The steep faces of the cuestas range in height from approximately 50 feet to 200 feet.

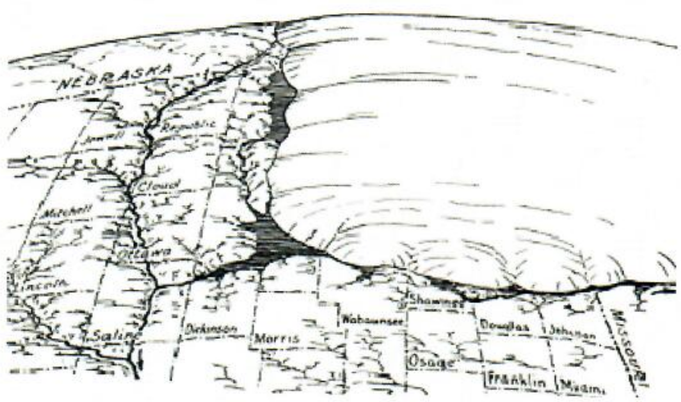
4. Flint Hills

Springtime in the Flint Hills, Chase County. *Image courtesy of Kansas Geological Survey.*

The Flint Hills are familiar to many travelers since this part of the state is traversed by both I-70 and the Kansas Turnpike. Despite disagreement about the exact boundaries of the Flint Hills, most geologists agree that the hills extend from Marshall County, in the north, to Cowley County, in the south. (Of course, the hills don't end abruptly at the state line; they continue into Oklahoma, where they are known as the Osage Hills.)

The Flint Hills were formed by the erosion of Permian age limestones and shales. During the early part of the Permian Period (which lasted from about 286 to 245 million years ago), shallow seas covered much of the state, as they did during Pennsylvanian times. Unlike the Pennsylvanian limestones to the east, however, the limestones in the Flint Hills contain numerous bands of chert, or flint. Because chert is much less soluble than the limestone around it, the weathering of the limestone has left behind a clayey soil full of cherty gravel. This gravel-filled soil covers the rocky uplands and slows the process of erosion. Most of the hilltops in this region are capped with this cherty gravel.

Because of the cherty soil, the land is better suited to ranching than farming. Because of this, the Flint Hills is still largely native prairie grassland, one of the last great preserves of tallgrass prairie in the country. The tall grasses in this region are mostly big and little bluestem, switch grass, and Indian grass. Except along stream and river bottoms, trees are rare. The streams in the Flint Hills have cut deep, precipitous channels. Streams cut in chert-bearing strata are narrow, box-like channels, whereas those cut in weaker shales are wider, more gently sloping valleys.



The glacier that extended into Kansas approx. 600,000 years ago carried quartzite boulders and glacial drift into northeastern Kansas. *Image courtesy of Kansas Geological Survey.*

5. Glaciated Region

True to its name, this part of Kansas was glaciated— that is, it was covered by at least two of the eight or nine glaciers that encroached upon much of the northern United States during the Pleistocene Epoch (1.6 million to 10,000 years ago). The first of these covered just the northeastern corner of Kansas. The second, which encroached on Kansas about 600,000 years ago, extended almost to Manhattan and beyond Topeka and Lawrence in a line roughly parallel to the present-day Kansas River. In places this ice sheet was 500 feet thick.

The underlying bedrock in the Glaciated Region is Pennsylvanian and Permian limestones and shales that dip gently to the west and northwest. These rocks, however, have been covered by thick glacial deposits—silt, pebbles, and boulders—that were left behind when the ice melted. In some places, the thick deposits, which geologists call glacial drift, have formed deep soils.

6. High Plains

In Kansas, the High Plains region comprises almost all of the western one-third of the state. It is an area of vast flatlands and gently rolling hills, with topographic relief largely restricted to streams and river valleys, such as the Arikaree Breaks in Cheyenne County or along the Cimarron River in Seward County.

The High Plains developed on sediments that originated in the Rocky Mountains to the west. The Rocky Mountains were formed by deformations of the earth's crust at intervals during the last part of the Cretaceous Period and continuing into the Tertiary Period, which lasted from approximately 66 to 1.6 million years ago. By late Tertiary time, just a few million years ago, the Rockies were being eroded by wind and water. Streams flowing eastward out of the Rocky Mountains were full of sand, gravel, silt, and other rock debris. Over millions of years, this mass of eroded material filled the stream valleys and eventually covered the hills, creating a huge, gently sloping floodplain. The remnants of that region (which extends far beyond the Kansas border) is the region we call the High Plains.

The great wedge of sand and gravel that lies below the surface is the Ogallala Formation. The Ogallala is made up of the unconsolidated deposits (sands, gravels, clays, and other materials) that eroded off the face of the Rockies. Some of this material was cemented together to form porous sandstones, which are known as mortar beds. Most of the Ogallala is underground, but it crops out in many places, such as at Scott County State Lake. The Ogallala is one of the chief sources of ground water in western Kansas.

Elephant Rock in northwestern Decatur County is an eroded outcrop of the Ogallala Formation. *Image courtesy of Kansas Geological Survey.*

The High Plains get less precipitation than other parts of the state, averaging between 15 and 25 inches a year. The combination of low precipitation, windiness, and abundant sunshine makes for a dry, or semiarid, climate in much of the High Plains. Short, drought-tolerant grasses cover the uncultivated areas, trees are scarce, and desert-type plants (such as cactus and yucca) are common.

7. Arkansas River Lowlands & Wellington-McPherson Lowlands

The Arkansas River Lowlands and the Wellington-McPherson Lowlands, though separated into different physiographic regions, are geologically similar. Both regions are relatively flat alluvial plains, made up of sand, silt, and gravel that were dumped by streams and rivers.

The Arkansas River Lowlands is made up of rocks deposited by the Arkansas River during the last 10 million years as the river flowed through Kansas from its source high in the Rocky Mountains. In the Rockies, the Arkansas is supplied with runoff, snowmelt, and rock debris that weathers from the mountains, but as it moves out onto the High Plains, it receives little in the way of additional water. In fact, it loses water to its sandy riverbed. As its flow decreases, the river's ability to carry sediments also diminishes and it begins to dump its sediment load. It changes from a degrading stream (one that cuts downward in its channel) to an aggrading stream (one that builds up the riverbed).

The Wellington-McPherson Lowlands of south-central Kansas is also developed on alluvial deposits. This sand, silt, and gravel was eroded from slightly older rocks in the High Plains to the north, then carried by streams flowing south into the Arkansas River between one and two million years ago, during the Pleistocene Epoch.

The Wellington-McPherson Lowlands sit on top of one of the largest salt deposits in the world. Known as the Hutchinson salt bed, this deposit underlies much of central Kansas and is as much as 400 feet thick in places. Another important underground feature of the Wellington-McPherson Lowlands is the Equus Beds aquifer. The Equus Beds is made up of thick (more than 250 feet) deposits of silt, sand, and gravel, in many places saturated with water. This aquifer is an important source of water for Wichita, McPherson, Newton, and other communities in this region. These Pliocene- and Pleistocene-age deposits were named for fossils of Ice Age horses that were found among the unconsolidated deposits (*equus* is the Latin word for horse).

Sand dunes, formed by wind and water, occur in many places in both regions. Most of these dunes are covered with grass and other vegetation, which keeps the sand from shifting. Such sand dunes are considered inactive—that is, they are no longer moving in response to wind and water.

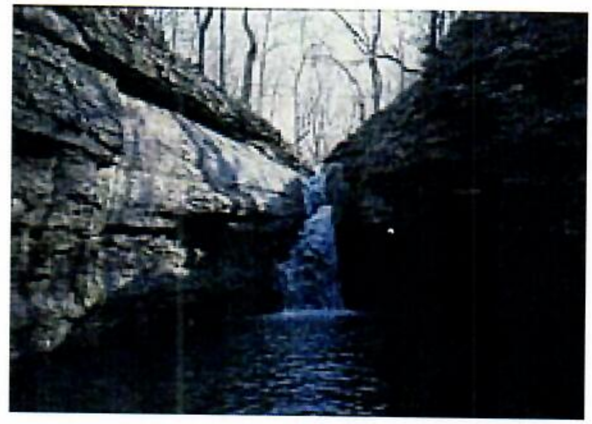
8. Ozark Plateau

As its name suggests, this corner of southeastern Kansas is part of the Ozarks of Missouri, Oklahoma, and Arkansas. Bounded by the Spring River on the west, the Ozark Plateau covers about 55 square miles and includes the towns of Baxter Springs and Galena. This region contains the oldest surface rocks in the state, limestones that formed about 345 million years ago during the latter part of the Mississippian Period.

These rocks show that during the Late Mississippian, the land was alternately above and below sea level. When the sea advanced, limestones (and occasionally shales) were deposited. When the sea retreated, erosion set in.

The Mississipian limestones contain chert (or flint). Because chert is much harder and more resistant to weathering than limestone, erosion of the softer limestone has left a thick blanket of chert gravel on hilltops and ridges.

The thin and rocky soil of the region, combined with steep slopes, makes most of the region unsuitable for farming. Cropland is restricted to the valley floors of Shoal Creek and Spring River. Many of the hillsides are covered with hardwood forests, predominantly oaks and hickories, along with other trees, shrubs, and vines. Some of the vegetation, such as sassafras trees and mistletoe, is not found anywhere else in the state.


Water flows over Mississippian limestone. *Image courtesy of Kansas Geological Survey.*

The Ozark Plateau averages more than 40 inches of precipitation a year, making it one of the wettest places in the state. Water also affects the landscape of the region. Percolating through the joints and fractures of the Mississipian limestones, water creates caverns and feeds seeps and springs, which in turn drain into clear streams that flow over gravel beds in steep-walled valleys. These stream valleys produce the region's topographic relief.


Typical Red Hills topography. Image courtesy of the Kansas Geological Survey.

9. Red Hills

The rugged topography of the Red Hills doesn't fit the stereotypical portrait of the Kansas landscape. Located in southern Kansas, mostly in Clark, Comanche, and Barber counties, the Red Hills are part of the Permian deposits that geologists call red beds. They get their color from iron oxide (rust), which turns bright red when exposed to oxygen.

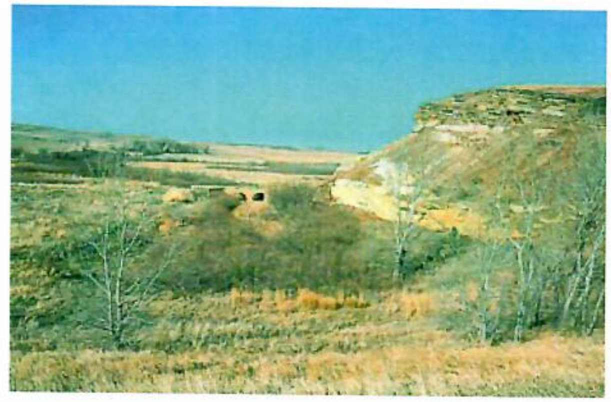
During the latter part of the Permian Period, about 260 million years ago, several thousand feet of brick-red shales, siltstones, and sandstones—along with inter-bedded layers of gypsum and dolomite—were deposited in Kansas. These Permian deposits have been exposed by erosion along the southern border of the state, forming a series of relatively flat-topped red hills, capped by light-colored gypsum or dolomite.

The Plains Indians, who called the major stream that flows from them the "Medicine River", knew the Red Hills as the "Medicine Hills". They believed that spirits in the hills and streams helped to cure their illnesses and hastened the healing of wounds. In fact, the Indians were on the right track: the waters of the springs and streams contain calcium and magnesium sulfates and other natural salts dissolved from the abundant gypsum and dolomite deposits in the region. Many of these chemical compounds have therapeutic and healing effects. For example, before antibiotics were discovered, a solution of magnesium sulfate, better known as Epsom Salts, was used to draw infection from wounds and to promote healing.

Sinkholes are common features of the Red Hills region. These sinkholes were probably formed by the dissolution of salt and gypsum beds several hundred feet below the surface. The land above then collapsed into the empty space, leaving a dip or sinkhole at the surface. Big Basin and Little Basin are two well-known sinkholes in western Clark County.

10. Smoky Hills

The region known as the Smoky Hills occupies the north-central part of the state. It is delineated by outcrops of Cretaceous-age rocks and takes its name from the early morning haze that often gathers in the valleys.



Outcrop of the Dakota Formation at Wilson Lake, Russell County. *Image courtesy of Kansas Geological Survey.*

During the Cretaceous Period (that interval of geologic time from about 144 to 66 million years ago), Kansas was once again under water. Unlike the relatively shallow seas of the Pennsylvanian and Permian, the seas that advanced and retreated during the Cretaceous were deeper and more widespread. Three principal rock outcrops characterize the Smoky Hills—the sandstones of the Dakota Formation, the limestones of the Greenhorn Limestone Formation, and the thick chalks of the Niobrara Chalk.

The Dakota Formation sandstones crop out in a wide belt from Rice and McPherson counties, in the south, to Washington County, in the north. They are the remains of beach sands and sediments dumped by rivers draining into the early Cretaceous seas. The hills and buttes in this part of the Smoky Hills, such as Coronado Heights in Saline County, are capped by this sandstone and rise sharply above the surrounding plains.

The next outcrop belt to the west is the Greenhorn Limestone, which is made up of thin (usually less than 6 inches) chalky limestones beds alternating with thicker beds of grayish shale. The Greenhorn Limestone was deposited in a relatively shallow part of the Cretaceous sea. Near the top of the Greenhorn is a limestone bed called Fencepost limestone. Because timber was scarce in this part of the state, limestone was used extensively by early settlers for buildings and fenceposts.

The third and westernmost range of hills in the Smoky Hills developed on the thick chalks of the Niobrara Chalk. These chalk beds, which were deposited in the deeper part of the Cretaceous ocean, are exposed in bluffs of the Solomon, Saline, and Smoky Hill rivers and in an irregular belt from Smith and Jewell counties to Finney and Logan counties. The Niobrara chalk is known for the pinnacles, spires, and odd-shaped masses formed by chalk remnants, such as Castle Rock and Monument Rocks in Gove County. It is also known for fossils of swimming reptiles such as plesiosaurs and mosasaurs that lived in the ocean while dinosaurs roamed the land.

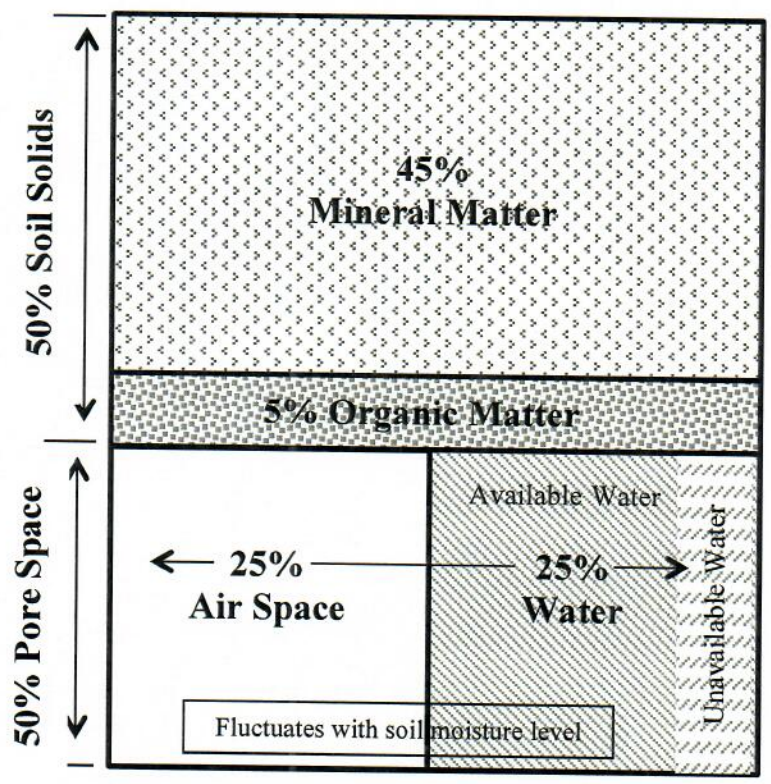
E. Introduction to Soils

Soil is formed when rock (parent material) is broken down by climate and vegetation over time. It is weathered rock fragments and decaying remains of plants and animals (organic matter). It also contains varying amounts of air, water and microorganisms. It furnishes mechanical support and nutrients for growing plants. Fertilizer is not plant food; plants produce their own food via photosynthesis using water, carbon dioxide, and energy from the sun. This food (sugars and carbohydrates) is combined with the plant nutrients to produce protein, enzymes, vitamins, and other elements essential for plant growth.

1. Soil Composition

A desirable surface soil in good condition for plant growth contains approximately 50% solid material and 50 percent open or pore space. The mineral component usually is made up of many different kinds and sizes of particles, ranging from those visible to the unaided eye to particles so small that they can only be seen with the aid of a very powerful (electron) microscope. This mineral material comprises about 45 percent to 48 percent of the total volume.

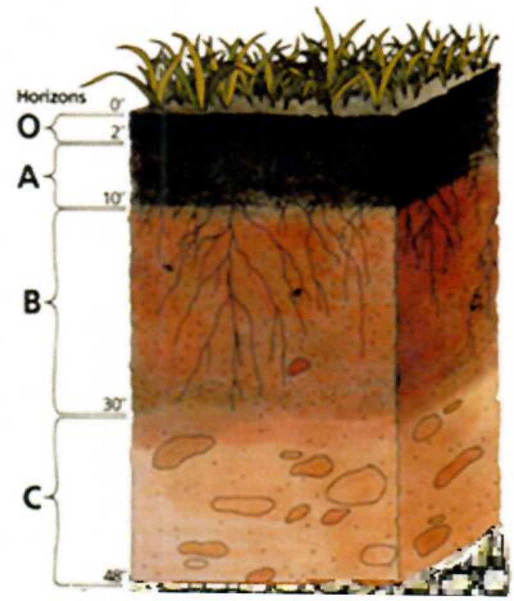
Organic material makes up about 2 percent to 5 percent of the volume and may contain both plant and animal material in varying stages of decomposition. Under ideal or near ideal moisture conditions for growing plants, soil or pore spaces contain about 25% air and 25% water based on the total volume of soil.



Soil solids, water and air relationship.

2. Soil Horizons or Layers

Soils have several layers, called horizons, each which has several distinguishing characteristics:



O Horizon = the surface leaf litter covering the soil. This horizon typically consists of fallen leaves and is only a few centimeters thick.

A Horizon = the topsoil. It usually extends 10-30 cm below the soil surface. In most fertile soils, the A horizon is 10% - 15% organic matter, which gives it a dark color.

B Horizon = consists of larger soil particles than those in the A horizon and extends 30-60 cm below the soil surface. This horizon usually contains relatively little organic mater ad is therefore lighter in color than the overlying A horizon. In many regions, the B horizon contains larger amounts of minerals and clay particles washed by rainfall from the A horizon. Mature roots commonly extend into the B horizon, where minerals accumulate. The B horizon is often called subsoil.

C Horizon = occurs 90 – 120 cm below the soil surface and consists primarily of partially altered to unaltered rock fragments and mineral grains. This horizon usually lacks organic matter and is often referred to as the **parent material**, since it is the raw material from which soil forms. The C horizon extends to the underlying and often impenetrable bedrock of igneous, sedimentary, or metamorphic rock. The parent material influences soil texture, natural fertility, rate of decomposition (and thus rate of soil formation), acidity, depth, and in some cases, topography (or lay of the land) on which the soil is formed.

3. Physical Properties of Soil

The physical properties of a soil are those characteristics which can be seen with the eye or felt between the thumb and fingers. They are the result of soil parent materials being acted upon by climatic factors (such as rainfall and temperature), and affected by topography (slope and direction, or aspect) and vegetation (kind and amount, such as

forest or grass) over a period of time. A change in anyone of these influences usually results in a difference in the type of soil formed. Important physical properties of a soil are color, texture, structure, drainage, depth, and surface features (stoniness, slope and erosion).

a. Color

Soil color is determined by organic matter content, drainage conditions, and degree of oxidation (extent of weathering). The higher the organic matter content (carbon-containing molecules), the darker the soil.

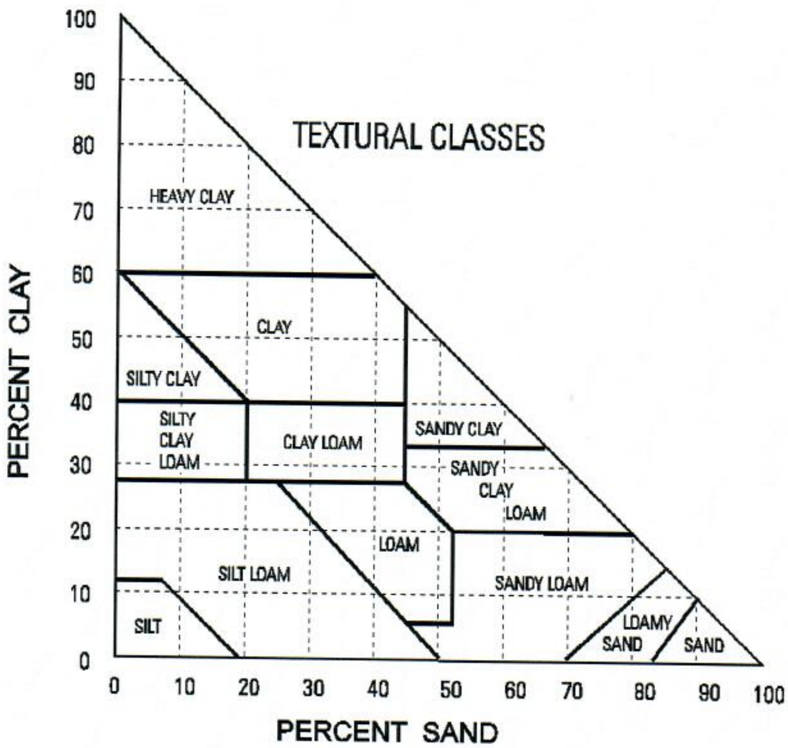
Surface soil colors vary from almost white, through shades of brown and gray, to black. Light colors indicate low organic matter content, and dark colors can indicate high content. Light or pale colors in the surface soil are frequently associated with relatively coarse texture, highly leached conditions, and high annual temperatures. Dark colors may result from high water table conditions (poor drainage), low annual temperatures, or other influences that induce high organic matter content and slow the oxidation of organic materials. However, soil coloration may be due to the colors imparted by parent material. Shades of red or yellow, particularly where associated with relatively fine textures, usually indicate that subsoil material has been incorporated in the surface layer.

Yellow colored subsoils usually indicate some drainage impediment. Most mottled subsoils, especially those where gray predominates, have too much water and too little air (oxygen) much of the time. The red-to-brown color of subsoils comes from iron coatings under well-aerated conditions. In wet soils with low oxygen levels, the iron coatings are chemically and biologically removed, and the gray color of background soil minerals shows.

b. Texture

Texture refers to the relative amounts of differently sized soil particles, or the fineness/ coarseness of the mineral particles in the soil. Soil texture depends on the relative amounts of sand, silt, and clay. In each texture class, there is a range in the amount of sand, silt, and clay that class contains.

Sand – large, coarse mineral particles of the soil that can be seen without a magnifying glass. Sand particles vary in size but all feel rough when rubbed between the thumb and fingers.



To determine soil texture, calculate percent sand and clay. Draw a vertical (sand) and horizontal (clay) line respectively. The soil texture is where these two lines intersect.

Silt - relatively fine soil particles that feel smooth and floury. When wet, silt feels smooth but is not slick or sticky. When dry, it is smooth, and if pressed between the thumb and finger, will retain the imprint. Silt particles are so fine they usually cannot be seen without a microscope.

Clays - are the finest soil particles. Clay particles can be seen only with the aid of a very powerful microscope. They feel extremely smooth when dry, and become slick and sticky when wet. Clay will hold the form into which it is molded.

Loam - is a textural class of soil that has moderate amounts of sand, silt and clay. Loam contains approximately 7-27% clay, 28-50% silt, and 50% sand.

There are approximately 20 classes of soil texture. Each class name indicates the size of the mineral particles that are dominant in the soil. Texture is determined in the field by rubbing moist to wet soil between the thumb and fingers. These observations can be checked in the laboratory by mechanical analysis or by separation into clay, silt, and various sized sand groups. Regardless of textural class, all soils in Kansas contain sand, silt, and clay, although the amount of a particular particle class may be small.

c. Drainage

Soil drainage is defined as the rate and extent of water movement in the soil, including movement across the surface as well as downward through the soil. Slope is a very important factor in soil drainage. Other factors include texture, structure, and physical condition of surface and subsoil layers. Soil drainage is indicated by soil color. Clear, bright colors indicate well-drained soils. Mixed, drab, and dominantly gray colors indicate imperfection in drainage. Low-lying areas within the landscape receive run-off water. Frequently, the water from these areas must escape by lateral movement through the soil or by evaporation from the surface, as poor structure and other physical influences do not allow drainage through the soil.

Too much or too little water in the soil is equally undesirable. With too much water, most plants will suffocate. Where there is too little water, plants will wilt and eventually die. The most desirable soil moisture situation is one in which approximately one-half of the pore space of the surface soil is occupied by water.

d. Depth

The effective depth of a soil for plant growth is the vertical distance into the soil from the surface to a layer that essentially stops the downward growth of plant roots. The barrier layer may be rock, sand, gravel, heavy day, or a partially cemented layer.

Soils that are deep well-drained, and have desirable texture and structure are suitable for the production of most crops. Deep soils can hold more plant nutrients and water than can shallow soils with similar textures. Depth of soil and its capacity for nutrients and water frequently determine the yield from a crop, particularly annual crops grown through the summer months.

Plants growing on shallow soils also have less mechanical support than those growing in deep soils. Trees growing in shallow soils are more frequently blown over by wind than are those growing in deep soils.

e. Erosion

Soils that have lost a part or their entire surface usually are harder to till and have lower productivity than those that have desirable thickness of surface soil. To compensate for surface soil loss, better fertilization, liming, and other management practices should be used. Increasing the organic matter content of an eroded soil often improves its tillage characteristics, as well as its water and nutrient capacity.

The principal reasons for soil erosion in Kansas are:

- insufficient vegetative cover
- overexposure through the use of cultivated crops on soils not suited to cultivation
- improper equipment and methods used in preparation and tillage of the soil

Soil erosion can be held to a minimum by:

- producing crops to which the soil is suited
- adequate fertilization and liming to promote vigorous growth of plants
- thorough soil preparation
- proper tillage methods
- mulching