Soil Characterization Protocol

Purpose

To characterize the physical and chemical properties for each horizon in a soil profile and prepare samples for further analysis

Overview

Students identify the horizons of a soil profile at a soil characterization site, then measure and record the top and bottom depth for each horizon. For each horizon, students describe the structure, color, consistence, texture, and abundance of roots, rocks, and carbonates. Samples are collected and prepared for additional laboratory analysis.

Student Outcomes

Students will be able to carry out field methods for soil analysis, record field data, and prepare soil samples for laboratory testing. Students will be able to relate the physical and chemical properties of soil at a site to the climate, landscape position, parent material, and land cover of an area.

Science Concepts

Earth and Space Sciences

Soils have properties of color, texture, structure, consistence, density, pH, fertility; they support the growth of many types of plants.

The surface of Earth changes.

Soils are often found in layers, with each having a different chemical composition and texture.

Soils consist of minerals (less than 2 mm), organic material, air and water.

Water circulates through soil changing the properties of both the soil and the water.

Physical Sciences

Objects have observable properties.

Scientific Inquiry Abilities

Identify answerable questions.

Design and conduct an investigation.

Use appropriate tools and techniques including mathematics to gather, analyze, and interpret data.

Develop descriptions and explanations, predictions and models using evidence.

Communicate procedures and explanations.

Time

Two-three 45-minute class periods or one 90-minute session in the field

Level

All

Frequency

Soil characterization measurements are taken one time for a specific soil site.

Collected samples can be stored for study and analysis at another time during the school year.

Materials and Tools

Spray bottle full of water

Golf tees, nails, or other horizon markers

Soil color book

Pencil or pen

Trowel, shovel, or other digging device

Paper towels

Meter stick or tape measure

Sealable bags or containers

Marking pen

Camera

Latex gloves

Acid bottle filled with vinegar

Hammer or other crushing tool

Rubber gloves

#10 Sieve (2 mm mesh openings)

Sheets of paper or paper plates

Soil Characterization Data Sheet

Prerequisites

Selecting, Exposing, and Defining a Soil Characterization Site Protocol

Soil Characterization Protocol – Introduction

Soil can be characterized by its structure, color, consistence, texture, and abundance of roots, rocks, and carbonates. These characteristics allow scientists to interpret how the ecosystem functions and make recommendations for soil use that have a minimal impact on the ecosystem. For example, soil characterization data can help determine whether a garden should be planted or a school should be built. Soil characterization data can help scientists predict the likelihood of flooding and drought. It can help them to determine the types of vegetation and land use best suited to a location. Soil characteristics also help explain patterns observed from satellite imagery, vegetation growth across the landscape, or trends of soil moisture and temperature that might be related to weather.

Teacher Support

Advance Preparation

Before beginning the *Soil Characterization Protocol* follow the protocol for *Selecting, Exposing, and Defining a Soil Characterization Site*. The *Soil Characterization Protocol* can be performed on a soil profile that is exposed in a pit, from an auger, or from a sample taken at the soil surface.

Teachers should have students bring in soil samples from home or from the school yard to practice each soil characterization measurement before doing the soil characterization protocol in the field.

Before starting the soil characterization, teachers should have students step back from the exposed profile and observe any obvious characteristic changes that occur with depth such as changes in color and structure.

To help demonstrate to students what happens when an acid (vinegar) is added to a base (free soil carbonates) teachers can mix baking soda into a dry soil and squirt vinegar from an acid bottle on to the soil to illustrate strong effervescence.

Measurement Procedures

To help identify different horizons, teachers should have students look for changes that might be obvious with depth including color, structure, texture, number and kind of roots and rocks, temperature, moisture, smell, sound (determined by rubbing peds together with their fingers).

It is helpful if students reach a consensus about what they are observing. For example, they may discuss until they finally agree to the placement of horizon boundaries, soil color, structure, texture, or other characteristics. The results based on student consensus should be recorded.

Questions for Guiding Students

What prompted you to choose the different horizons? Were your choices based on soil characteristics such as color, structure, presence of animals or roots?

If there was anything unusual about the soil profile? What may have caused this?

What can you tell about the formation of the soil by looking at the horizons in the profile?

Questions for Further Investigation

What creates the different horizons in a soil profile?

What natural changes could alter the soil horizons?

How long might it take to alter the depths of the different horizons?

How do soil profiles change from one location to another?

How do soil horizons change from one location to another?

Soil Characterization Protocol
Field Guide

Task

Identify, measure and record the horizons in a soil profile at a Soil Characterization Site. Measure and record the physical and chemical properties that characterize each horizon. Photograph the soil profile. Collect soil samples from each horizon.

What You Need

- ❑ Spray mist bottle full of water
- ❑ Golf tees, nails or other marking device that can be pushed into a soil horizon
- ❑ Trowel, shovel, or other digging device
- ❑ Soil color book
- ❑ Marking pen
- ❑ Camera
- ❑ Acid bottle filled with distilled vinegar
- ❑ *Soil Characterization Data Sheet*
- ❑ Pencil or pen
- ❑ Paper towels
- ❑ Meter stick or tape measure
- ❑ Rolling pin, hammer, or other utensil for crushing peds and separating particles

In the Field

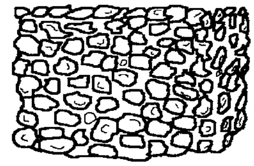
Identifying and Measuring Horizons

1. Make sure the sun shines on the profile if possible.
2. Use a trowel to scrape a few centimeters of soil off of the profile to expose a fresh soil face.
3. Determine whether the soil profile is moist, wet, or dry. If the soil profile is dry, moisten it with the spray mist bottle.
4. Start at the top of the profile and observe the characteristics of the soil moving towards the bottom of the profile.
5. Look carefully at the soil profile for distinguishing characteristics such as color, texture, shapes, roots, rocks, small dark nodules (called *concretions*), worms, small animals, insects, and worm channels. These observations will help to define the horizons.
6. Working in a straight vertical line, place a marker (such as a golf tee or nail) at the top and bottom of each horizon to clearly identify it. Be sure there is a consensus from all of the students regarding the depths of the soil horizons.
7. Measure the top and bottom depth of each horizon beginning at the top (surface) of the profile. Start with the meter stick or tape measure at 0 cm at the top of the profile. Note the depths at which each horizon starts and ends.
8. Record the top and bottom depth of each horizon on the *Soil Characterization Data Sheet.*

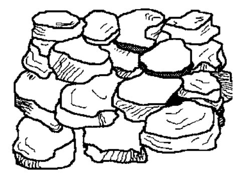
Measuring Structure

1. Use a trowel or other digging device to remove a sample of soil from the horizon being studied.
2. Hold the sample gently in your hand and look closely at the soil to examine its structure.
3. Come to a consensus with other students in the group on the type of soil structure of the horizon. Possible choices of soil structure are:

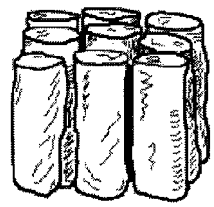
Granular: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.

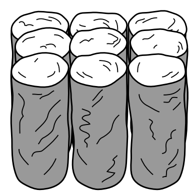
Blocky: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.

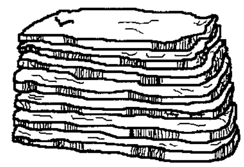
Prismatic: Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.

Columnar: Vertical columns of soil that have a white, rounded salt "cap" at the top. Found in soils of arid climates.

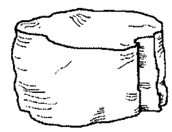
Platy: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.

In certain cases, soil samples may have no structure. These would be classified as either:

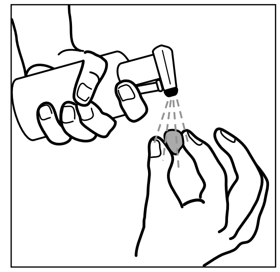
Single Grained: Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.

Massive: Soil has no visible structure, is hard to break apart and appears in very large clods.

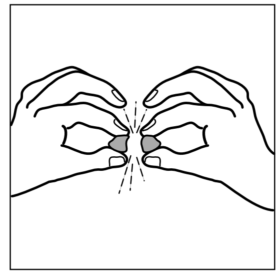



4. Record the structure type on the *Soil Characterization Data Sheet.*

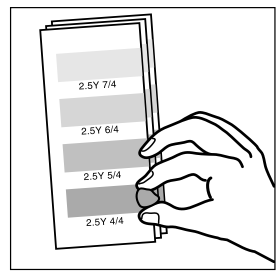
Measuring Main Color and Second Color



1. Take a ped from the horizon being studied and note whether it is moist, dry, or wet. If it is dry, moisten it slightly with water from your water bottle.



2. Break the ped and hold it next to the color chart.
3. Stand with the sun over your shoulder so that sunlight shines on the color chart and the soil sample you are examining.

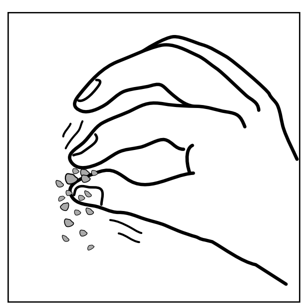


4. Find the color on the color chart that most closely matches the color of the inside surface of the ped. Be sure that all students agree on the choice of color.
5. Record on the *Soil Characterization Data Sheet* the symbol of the color on the chart that most closely matches the soil color that covers the largest area of the ped (dominant or main color). Sometimes, a soil sample may have more than one color. Record a maximum of two colors if necessary, and indicate (1) the dominant (main) color, and (2) the sub-dominant (second) color.

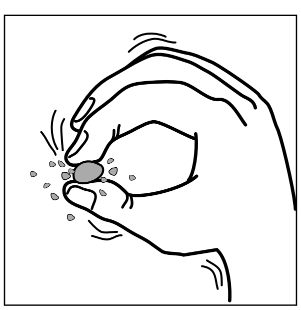
Measuring Soil Consistence

1. Take a ped from the soil horizon being studied. If the soil is very dry, moisten the face of the profile by squirting water on it, and then remove a ped for determining consistence.
2. Holding the ped between your thumb and forefinger, gently squeeze it until it pops or falls apart.
3. Record one of the following categories of soil ped consistence on the *Soil Characterization Data Sheet.*

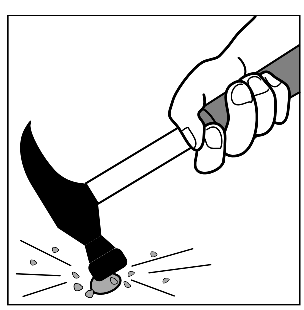
Loose: You have trouble picking out a single ped and the structure falls apart before you handle it. **Note:** Soils with **single grained structure always** have **loose consistence**.



Firm: The ped breaks when you apply a larger amount of pressure and the ped dents your fingers before it breaks.



Friable: The ped breaks with a small amount of pressure.



Extremely Firm: The ped can't be crushed with your fingers (you need a hammer!)

Measuring Soil Texture (for help with this category, refer to the Textural Triangle under "Frequently Asked Questions")

Step 1

- Place some soil from a horizon (about the size of a small egg) in your hand and use the spray mist bottle to moisten the soil. Let the water soak into the soil and then work it between your fingers until it is thoroughly moist. Once the soil is moist, try to form a ball.
- If the soil forms a ball, go on to **Step 2.** If the soil does not form a ball, call it a **sand**. Soil texture is complete. Record the texture onto the *Soil Characterization Data Sheet.*

Step 2

- Place the ball of soil between your thumb and index finger and gently push and squeeze it into a ribbon. If you can make a ribbon that is longer than 2.5 cm, go to **Step 3.** If the ribbon breaks apart before it reaches 2.5 cm, call it a **loamy sand**. Soil texture is complete. Record the texture onto the *Soil Characterization Data Sheet.*

Step 3

- If the soil:
  - Is very sticky
  - Hard to squeeze
  - Stains your hands
  - Has a shine when rubbed
  - Forms a long ribbon (5+ cm) without breaking,

Call it a clay and go to Step 4.

Otherwise, if the soil:

- Is somewhat sticky
- Is somewhat hard to squeeze
- Forms a medium ribbon (between 2-5 cm)

Call it a clay loam and go to Step 4.

Otherwise, if the soil is:

- Smooth
- Easy to squeeze,
- At most slightly sticky,
- Forms a short ribbon (less than 2 cm)

Call it a loam and go to Step 4.

Step 4

- Wet a small pinch of the soil in your palm and rub it with a forefinger. If the soil:
  - Feels very gritty every time you squeeze the soil, go to **A.**
  - Feels very smooth, with no gritty feeling, go to **B.**
  - Feels only a little gritty, go to **C.**

A. Add the word **sandy** to the initial classification.

- Soil texture is either:
  - sandy clay,
  - sandy clay loam, or
  - sandy loam
- Soil texture is complete. Record the texture onto the *Soil Characterization Data Sheet.*

B. Add the word **silt or silty** to the initial classification.

- Soil texture is either:
  - silty clay,
  - silty clay loam, or
  - silt loam
- Soil texture is complete. Record the texture onto the *Soil Characterization Data Sheet.*

C. Leave the original classification.

- Soil texture is either:
  - clay, clay loam, or loam
- Soil texture is complete. Record the texture onto the *Soil Characterization Data Sheet.*

Measuring Rocks

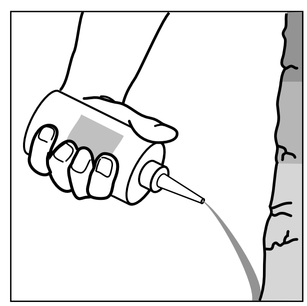
1. Observe and record if there are **none**, **few**, or **many** rocks or rock fragments in the horizon. A rock or rock fragment is defined as being larger than 2 mm in size.
2. Record your observation on the *Soil Characterization Data Sheet.*

Measuring Roots

1. Observe if there are **none**, **few**, or **many** roots in each horizon.
2. Record your observation on the *Soil Characterization Data Sheet.*

Measuring Free Carbonates

1. Set aside a portion of the exposed soil to use for the free carbonates test. Make sure not to touch it with your bare hands.
2. Open the acid bottle and squirt vinegar on the soil particles, starting from the bottom of the profile and moving up. Be sure to use caution and point the bottle directly at the soil, not toward other students, especially toward eyes. If vinegar gets into your eyes, rinse with water for 15 minutes.



3. Look carefully for the presence of effervescence. The more carbonates that are present, the more bubbles (effervescence) you will observe.
4. For each horizon, record on the *Soil Characterization Data Sheet* one of the following as the result of the Free Carbonate Test:
   - **None:** if you observe no reaction, the soil has no free carbonates present.
   - **Slight:** if you observe a very slight bubbling action; this indicates the presence of some carbonates.
   - **Strong:** if there is a strong reaction (many, and/or large bubbles) this indicates that many carbonates are present.

Photographing the Soil Profile

1. Place a tape measure or meter stick starting from the top of the soil profile next to where the horizons have been marked.
2. With the sun at your back, photograph the soil profile so that the horizons and depths can be seen clearly.
3. Take another photograph of the landscape around the soil profile.
4. Submit photos to GLOBE following directions outlined in the *How to Submit Photos and Maps* section of the *Implementation Guide.*

Horizon Sampling
Field Guide

Task

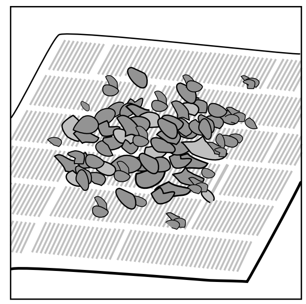
Collect soil samples of each horizon.

What You Need:

- ❑ Trowel, shovel or other digging device
- ❑ Latex gloves
- ❑ Sealable bag or container
- ❑ Marking pen
- ❑ Sheets of paper or paper plates for drying
- ❑ #10 Sieve (2 mm mesh openings)

In the Field

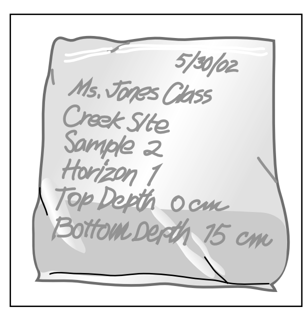
Collecting Soil Samples



1. Dig out a large soil sample from each soil horizon. Avoid the area of the soil face that was tested for carbonates and avoid touching the soil samples so that pH measurements will not be contaminated by acids on your skin.
2. Place each sample in a bag or other soil container
3. Label each bag with the site name, horizon name, and top and bottom depths.
4. Bring these samples from the field and into the classroom or laboratory.

5. Spread the samples on separate paper plates or sheets of paper to dry in the air. You can place the soil near a window where it will receive light from the sun to make the drying go faster.
6. Put on latex gloves so the acids on your skin do not contaminate the soil pH measurement.
7. Put the #10 (2 mm openings) sieve on top of clean sheets of paper and pour the dry soil sample into the sieve.

8. Carefully push the dried soil material through the mesh onto the paper. Do not force the soil through the sieve or you may bend the wire mesh openings. Rocks will not pass through the mesh and will stay on top of the sieve. Remove the rocks (and other pieces of debris) from the sieve and discard. If no sieve is available, carefully remove the rocks and debris by hand.
9. Transfer the rock-free, dry soil from the paper under the sieve into new, clean, dry plastic bags or containers.



10. Seal the containers, and label them the same way that they were labeled in the field (horizon name, top and bottom horizon depth, date, site name, site location). This is the soil that will be used for lab analyses.
11. Store these samples in a safe, dry place until they are used.

Frequently Asked Questions

What do the numbers and letters describing the soil color mean?

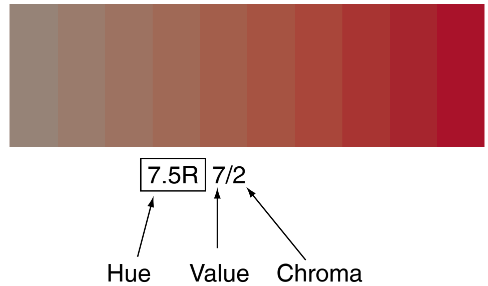
For GLOBE, the universal Munsell notation is used to identify the color of the soil.

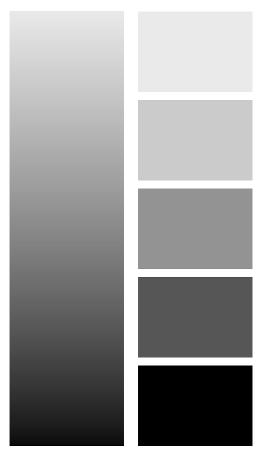
The system is made up of 3 symbols representing the *hue, value,* and *chroma* of the soil color.

The **hue** is described by the first set of number and letter symbols in the Munsell system. Hue represents the position of the color on the color wheel (Y=Yellow, R=Red, G=Green, B=Blue, YR=Yellow Red, RY=Red Yellow).

The **value** is the number before the slash in the Munsell system. Value indicates the lightness of a color. The scale of value ranges from 0 for pure black to 10 for pure white.

The **chroma** is the number after the slash in the Munsell system. Chroma describes the "intensity" of a color. Colors of low chroma values are sometimes called weak, while those of high chroma are said to be highly saturated, strong, or vivid. The scale starts at zero, for neutral colors, but there is no arbitrary end to the scale.

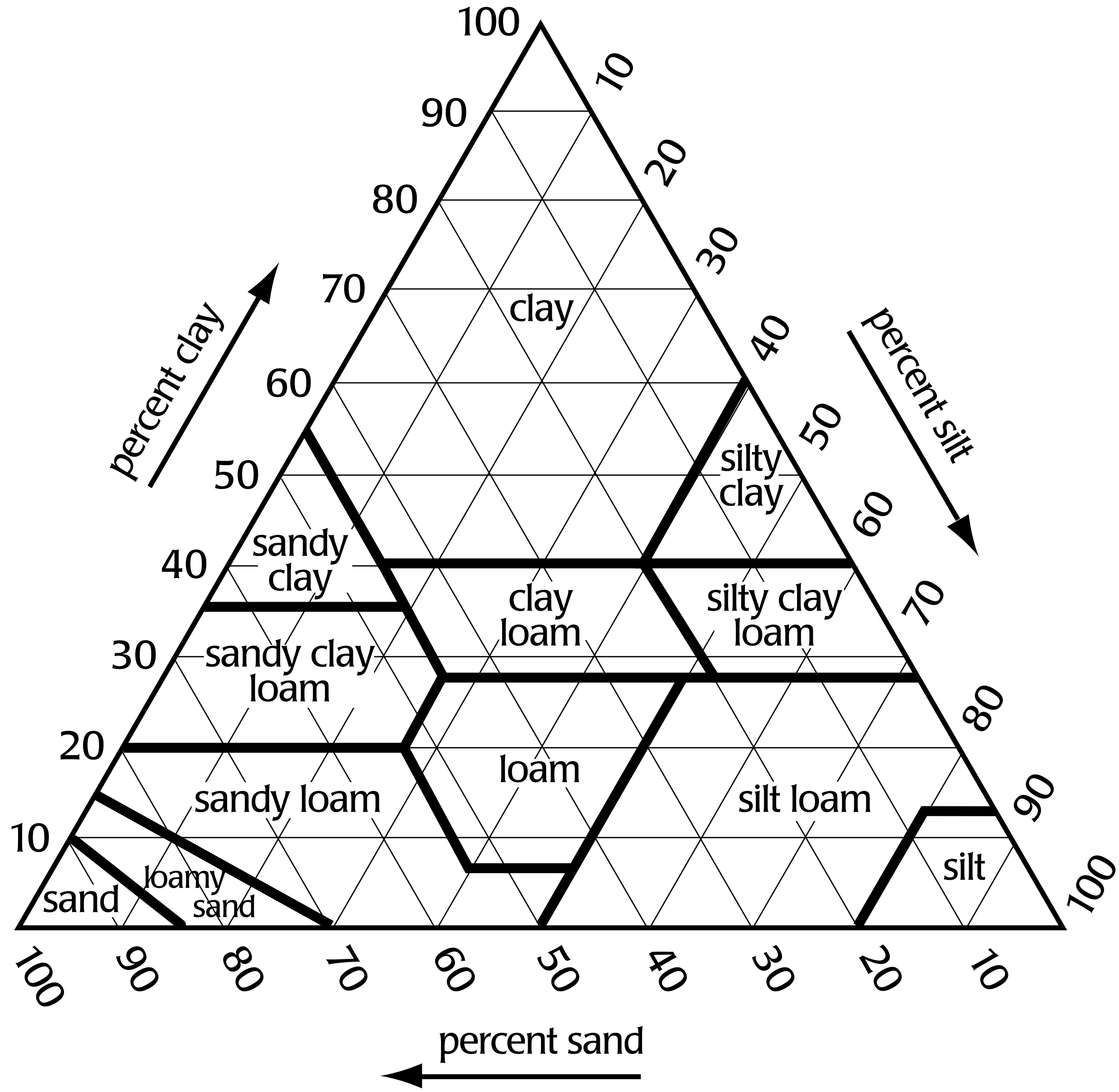




What does it mean if I determine that my soil is a silty clay or a sandy loam?

The texture you determine from feeling your soil is a subjective measurement. This means that another person might not think that the soil has exactly the same texture as you do. The texture actually refers to the percentages of sand, silt, and clay present. The triangle below is called a textural triangle and can be used to determine the approximate percentages of sand, silt, and clay in your soil from the texture you determined. For a more objective measure of soil texture, you should perform the *Particle Size Distribution Protocol* in which you determine the actual percentages of sand, silt, and clay in the soil.

Figure SO-SC-1: Soil Textural Triangle



Soil Characterization Protocol – Looking at the Data

Are the data reasonable?

Soil profiles vary greatly from one region to another making it difficult to predict what students will see at their sites. There are certain things that teachers and students can look for to tell whether or not the data are reasonable.

Horizons

It is unlikely that large numbers of distinct horizons will be found in very young soils (recently deposited, or close to bedrock), or very highly developed soils (such as are found in tropical regions). More horizons are found in temperate climates under forest vegetation.

Color

Dark colored soil is usually found at the surface, unless there has been intense leaching of organic material, such as in a coniferous forest, or deposition has occurred where new parent material has been deposited on top of a soil profile that was already developed.

Texture

In general, soil texture is similar as you go deeper into the soil, with a gradual increase in clay. If there is a very sharp difference in texture (such as a clayey soil over a very sandy soil) this may also be an indication of a different parent material due to deposition. This may occur if you are in an area near a stream where flooding is common, or where human activity has disturbed the soil and *fill* has been added. It is helpful to complete the *Particle Size Distribution Protocol* for each horizon to check the texture data collected in the field with actual lab measurements of the amount of sand, silt, and clay.

Structure

Granular structure is generally found where there are many roots. Soils with high amounts of clay typically have blocky or massive structure.

Consistence

When the soil has single grained structure, the consistence is always loose and the texture is usually sand or other very sandy texture such as loamy sand. Testing for the bulk density of the soil can act as a check for the consistence since the denser the soil, the more firm the consistence will be.

Roots

Bulk density should be lower when there are many roots in the soil that add pore space to the horizon.

Carbonates

If free carbonates are present, the pH should be 7 or above since high amounts of calcium carbonate decrease the soil acidity and increase the pH.

Student Research

Students at Queen Mary School in Pennsylvania, USA wanted to compare the soil at two sites near their school. The first site was in a forested area that had not been disturbed for at least 100 years. The second site was in a field that had been used for agriculture, but then became a grass field.

Mr. Hardy, the teacher, did a few things to prepare for this study. First, he contacted the local USDA Natural Resources Conservation Service office and asked the local soil scientist to come out and help the class. Arrangements were made so that the soil scientist could spend a class period talking about soils in the county and show the students maps and other information about the soils near their school. She also agreed to help the students with their soil characterization measurements. Second, Mr. Hardy checked to make sure that it was safe to dig at these sites, and contacted the students' parents to help dig the soil pits. The parents waited until a few days after a good rainfall so that the soil would be moist and easy to dig, and soon had dug two soil characterization pits to a depth of 1 meter. As they removed the soil from the pit, it was stacked neatly in piles by horizon, so that when the characterization was done, they could return the soil in the same order in which it had been removed.

When the day for digging arrived, the students went out in two teams to characterize each of the sites. Team A was in charge of the site description and determined the GPS location, elevation, slope, aspect, landscape position, cover type, and land use. They also identified the soil parent material with the help of geologic maps they found in the library and help from the county soil scientist. Information about the site location and other notes were also recorded. Team B went into the pit and did the soil characterization and sampling of horizons, making sure there was consensus among all the students on the team about what they were observing. The students waited until the following day to complete the characterization at the grass field site. Each team then switched roles so that every student had a chance to do both the site description and soil characterization in the pit. The data collected by the students at each site are given below.

Site A:
Slope: 15 degrees

Aspect: 120 degrees

Landscape Position: Summit

Cover Type: Trees

Land Use: Forest

Parent Material: Sandstone Bedrock (hit bedrock at 86 cm)

Horizon	Top	Bottom	Rocks	Roots	Structure	Color	Consistence	Texture	Carbonates
1	0cm	6cm	Few	Many	Granular	10YR 2/1	Friable	Sandy Loam	None
2	6cm	20cm	Few	Many	Blocky	10YR 6/4	Friable	Sandy Loam	None
3	20cm	50cm	Few	Few	Blocky	7.5YR 6/6	Firm	Clay Loam	None
4	50cm	70cm	Many	Few	Blocky	7.5YR 7/8	Firm	Sandy Clay Loam	None
5	70cm	86cm	Many	None	Single Grained	7.5YR 8/4	Loose	Loamy Sand	None

Site B:

Slope: 3 degrees

Aspect: 120 degrees

Landscape Position: Large Flat Area

Cover Type: Grass

Land Use: School Grounds

Parent Material: Limestone Bedrock

Horizon	Top	Bottom	Rocks	Roots	Structure	Color	Consistence	Texture	Carbonates
1	0cm	20cm	None	Many	Granular	10YR 3/4	Friable	Loam	None
2	20cm	40cm	None	Many	Blocky	7.5YR 6/8	Friable	Clay Loam	None
3	40cm	75cm	None	Many	Blocky	5YR 6/8	Firm	Clay Loam	None
4	75cm	100cm	None	Few	Prismatic	5YR 6/6	Extremely Firm	Clay	None

The students examined the results of their soil site characterizations and made the following observations:

Site A: Site A is located on top of a hill and is presently forested. The soil was formed from sandstone bedrock. The color of the soil was darkest at the top and got lighter with depth. The structure was granular where there were many roots, and became blocky with depth. The number of rocks increased closer to the bedrock. The soil texture changed with depth, becoming more clay-rich and harder to squeeze, but then becoming more sandy closer to the horizon just above the bedrock. The soil scientist explained that in this type of climate, clay will move down through the soil profile over time and accumulate or build up in the lower horizons. She also said that the sandy and rocky horizon at the bottom was from the sandstone parent material breaking up into soil material. Because the bottom horizon was loamy sand and had single grained structure, its consistence was loose and fell apart easily. Also, there were no carbonates because the parent material was carbonate-free sandstone.

Site B: The soil at site B was very different than at Site A, even though they are both on the school grounds and formed under the same climate. This was probably due to the difference in parent materials at the two sites.

The soil at site B was formed from limestone parent material along a wide flat surface. The original vegetation here was probably forest at one time, as it was for most of the state of Pennsylvania, but the trees had probably been cut away to create an agricultural field since it was such a wide and flat area. Some of the parents remembered that the land where pit B was dug was once a farm, but was converted to a grassy field when the school was built. The pit dug here was deeper than the pit at Site A since, according to the soil scientist, limestone rock is more easily weathered than sandstone which is harder. In fact, there were no rock fragments in the profile from the original bedrock since the limestone rocks were so easily weathered.

The soils at both sites A and B were darkest at the surface, because of the input of organic material from the vegetation at the surface, although as they got deeper, the soil color at Site A got lighter and the soil color at Site B got redder. The texture of the horizons at Site B was much more clay-rich. Again the soil scientist explained that this was common in most soils of this region because small clay-sized particles move down through the soil profile over time. Since there were so many more clay-sized particles in the limestone parent material than in the sandstone, the texture of the soil at Site B was also much more clay-rich. She also stated that it was common for clay-rich soils in this part of the world to have a high amount of iron oxide coating the particles which is what gives them the reddish color. The high clay content made the consistence of the soil very firm and difficult to break, and so there were few roots in this horizon. One of the constituents of limestone is calcium carbonate but there were no carbonates present in this profile. The soil scientist explained that again, because of the temperate climate and materials such as acids in organic matter which leach through the soil, any carbonates that may have been in this soil originally have been removed. If a soil derived from this kind of limestone parent material was formed in a drier climate, carbonates would be expected in the soil profile.