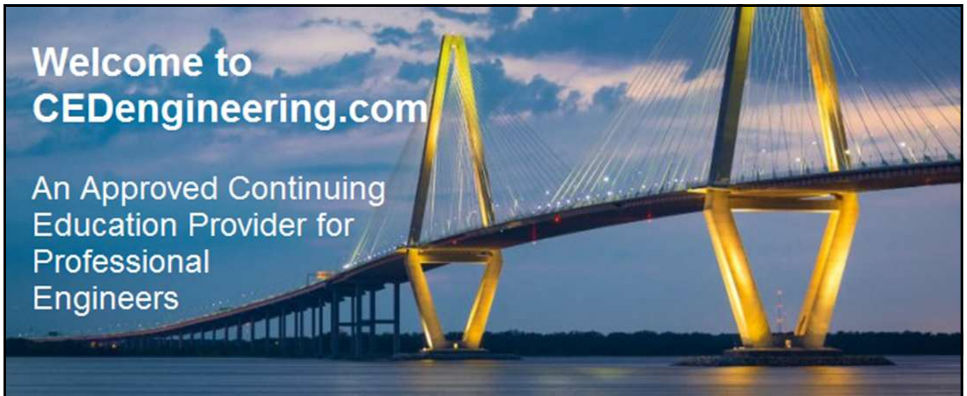

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SOIL SURVEY MANUAL

Course No: L03-302 - Course Credit: 3 PDH

Prepared by:

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LEARNING OBJECTIVES

1. To understand the terminology and concepts used in soil description, including pedons and the examination of soil profiles in field investigations.
2. To explain soil horizons and layers, including their designations and how they are used to describe soil profiles.
3. To examine near-surface subzones and root-restricting depth and their significance in soil interpretation and land use.
4. To explore soil particle-size distribution and soil texture, including the use of texture classes in soil classification.
5. To identify rock fragments, pararock fragments, artifacts, and compound texture modifiers, and their role in soil characterization.
6. To understand soil color and surface features as key indicators of soil composition, drainage conditions, and environmental processes.

EXAMINATION AND DESCRIPTION OF SOIL PROFILES

Introduction

- A description of the soils is essential in any soil survey.
- This chapter provides standards and guidelines for describing the soil.
- It contains standard technical terms and their definitions for most soil properties and features and provides information for describing the necessary related facts.
- For some soils, standard terms are not adequate and must be supplemented by a narrative.
- Some soil properties change through time.
- Many properties must be observed over time and summarized if one is to fully understand the soil being described and its response to short-term environmental changes.
- Examples are the length of time that cracks remain open, the patterns of soil temperature and moisture, and the variations in size, shape, and hardness of clods in the surface layer of tilled soils.

- This chapter does not discuss every possible soil property.
- For some soils, other properties need to be described.
- Good judgment is needed to decide what properties merit detailed attention for any given pedon (sampling unit).
- Observations must not be limited by preconceived ideas about what is important.

- Although the format of the description and the order in which individual properties are described are less important than the content of the description, a standard format has distinct advantages.
- The reader can find information more rapidly, and the writer is less likely to omit important features.
- Furthermore, a standard format makes data entry into a computer database more efficient.
- Any standardized forms need to allow enough space for all possible information.

- Each investigation of the internal properties of a soil is made on a soil body with certain dimensions.
- The body may be larger than a pedon (e.g., a backhoe pit) or represent only a portion of a pedon (e.g., a sample from a hand auger).
- During field operations, many soils are investigated by examining the soil material removed by a sampling tube or auger.
- For rapid investigations of thin soils, a small pit can be dug and a section of soil removed with a spade.
- All of these are samples of pedons.
- Knowledge of the internal properties of a soil is derived mainly from studies of such samples.

- Samples can be studied more rapidly than entire pedons; consequently, a much larger number can be studied and for several more places.
- For many soils, the information obtained from a small sample amply describes the pedon from which it is taken.
- For other soils, however, important properties of a pedon are not observable in a smaller sample and detailed studies of the entire pedon are needed.
- Complete study of an entire pedon requires the exposure of a vertical section and the removal of horizontal sections layer by layer.
- Horizons are studied in both horizontal and vertical dimensions.
- The kind of exposure (e.g., bucket auger, push tube, small hand-dug pit, backhoe pit, road cut, etc.) should be identified in the soil description.

General Terms Used to Describe Soils

- This section describes several of the general terms for internal elements of the soil.
- Other more specific terms are described or defined in the following sections.

Pedon

- A pedon is a three-dimensional body of soil that has sufficient area (roughly 1 to 10 m^2) and depth (up to 200 cm) to be used in describing the internal arrangement of horizons and in collecting representative samples for laboratory analysis.
- The pedon is the individual classified with Soil Taxonomy.
- Multiple pedons that have the same classification and occur together in landscapes are used in defining soil series.
- Conceptually, these contiguous pedons are called polypedons.

Soil Profile

- A soil profile is smaller than a pedon.
- It is exposed by a two-dimensional vertical cut through the soil.
- It is commonly conceived as a plane at right angles to the soil surface.
- In practice, a description of a soil profile includes soil properties that can be determined only by inspecting volumes of soil.
- However, the volume of soil described from a profile is almost always less than the volume of soil defined by a full pedon because observations of the soil profile are generally made to only a few decimeters behind the face of the exposed profile.
- A pedon description is commonly based on examination of a profile, and the properties of the pedon are inferred from the properties of the profile.
- The width of a profile ranges from a few decimeters to several meters or more.
- The size of the profile should be sufficient to include the largest structural units.

Soil Horizon

- A soil horizon is a layer, approximately parallel to the surface of the soil, that is distinguishable from adjacent layers by a distinctive set of properties produced by the soil-forming processes (i.e., pedogenesis).
- The term “layer” is used instead of “horizon” if the properties are inherited from the parent material, such as sedimentary strata.
- Horizons, in contrast, display the effects of pedogenesis, such as the obliteration of sedimentary strata and accumulation of illuvial clay.

Solum

- The solum (plural, sola) of a soil consists of a set of horizons that are related through the same period of pedogenesis.
- It includes all horizons now forming.
- It may also include a bisequum (discussed below).
- It does not include a buried soil or layer unless it has acquired some of its properties by currently active soil-forming processes.
- The solum of a soil is not necessarily confined to the zone of major biological activity.
- Its genetic horizons may be expressed faintly to prominently.
- A solum does not have a maximum or minimum thickness.

- Solum and soils are not synonymous.
- Some soils include layers that are not affected by soil formation.
- These layers are not part of the solum.
- The number of genetic horizons ranges from one to many.
- An A horizon that is 10 cm thick overlying bedrock is by itself the solum.
- A soil that consists only of recently deposited new soil material or recently exposed soft sediment generally does not have a solum.

- In terms of soil horizons as described in this chapter, a solum consists of O, V, A, E, and B horizons and their transitional horizons.
- Included are horizons with an accumulation of carbonates or more soluble salts if these horizons are either within, or contiguous to, other genetic horizons and are judged to be at least partly produced during the same period of soil formation.

- The lower limit of the solum, in a general sense, in many soils should be related to the depth of rooting for perennial plants, assuming that water state and chemistry are not limiting.
- In some soils, the lower limit can be set only arbitrarily and is defined in relation to the particular soil.
- For example, horizons of carbonate accumulation are easily visualized as part of the solum in many soils in arid and semiarid environments.
- However, to conceive of cemented horizons of carbonates that may extend for 5 meters or more below the surface as part of the modern solum is more difficult.
- Such massive carbonate horizons represent pedogenesis over hundreds of thousands of years and are referred to as relict paleosols.
- Gleyed soil material begins in some soils a few centimeters below the surface and continues practically unchanged to a depth of many meters.
- Gleying immediately below the A horizon is likely to be related to the processes of soil formation in the modern soil.
- At great depth, gleying is likely to be relict or related to processes that are more geological than pedological.
- The same kind of problem exists for some deeply weathered soils—the deepest material penetrated by roots is very similar to the weathered material at much greater depth.

- For some soils, digging deep enough to reveal all of the relationships between soils and plants is not practical.
- Plant roots, for example, may derive much of their moisture from fractured bedrock.
- Descriptions should indicate the nature of the soil-rock contact and determinations about the upper part of the underlying rock.
- Not everyone will agree about the exact extent of the solum in some soils.
- For example, a certain level of subjectivity is involved in differentiating transitional BC or CB horizons from C horizons or in determining which properties observed in the soil are the product of active pedogenic processes.
- The concept of the solum remains useful for discussions about the nature of soils and soil profiles but is generally not used as a part of any technical definitions.

Sequum

- A sequum (plural, sequa) consists of a B horizon and any overlying eluvial horizons.
- A single sequum is considered to be the product of a specific combination of soil-forming processes.
- Most soils have only one sequum, but some have two or more.
- For example, a new sequence of horizons that meet the criteria for a Spodosol can form in the upper part of a previously existing Alfisol, producing an eluviated zone and a spodic horizon underlain by another eluviated zone overlying an argillic horizon.
- Such a soil has two sequa. Soils in which two sequa have formed, one above the other in the same deposit, are said to be bisequal.

- If two sequa formed in different deposits at different times, the soil is not bisequal.
- For example, a soil having an A-E-B horizon sequence may form in material that was deposited over another soil that already had an A-E-B horizon sequence.
- Each set of A-E-B horizons is a sequum, but the combination is not a bisequum; the lower set is a buried soil.
- If the horizons of the upper sequum extend into the underlying sequum, the affected layer is considered part of the upper sequum.
- For example, the A horizon of the lower soil may retain some of its original characteristics and also have some characteristics of the overlying soil.
- In this case, the soils are also not considered bisequal; the upper part of the lower soil is the parent material of the lower part of the currently forming soil.
- In many soils the distinction cannot be made with certainty.
- If some of the C material of the upper sequum remains, the distinction is clear.

Studying Pedons

Site Selection

- Pedons representative of an extensive mappable area are generally more useful than pedons that represent a transitional area to another soil.
- For detailed study of a soil, a pedon is tentatively selected and then examined preliminarily to determine whether or not it represents the desired segment of the soil's range.
- This is a critical step.
- Typically, only a few pedons can be studied in detail due to the time and expense involved in exposing, describing, photographing, and sampling soil profiles and performing necessary laboratory analysis.
- It is very important that the site selected for study is a representative sample of the overall soil body in the landscape because data from the site will be used to classify the soil pedon and correlate it with other similar pedons.

Information Recorded

- For a soil description to be of greatest value, detailed information about its setting should be recorded.
- Important items include location (identified by latitude and longitude, including datum, or another acceptable geographic location system), the part of the landscape that the pedon represents (i.e., landform, position on landform, any applicable microfeature), elevation, aspect, parent material, vegetation, land use, and erosion or other disturbance affecting the soil profile.
- The level of detail will depend on the objectives.
- A complete setting description should include information about the pedon and other soils conterminous with the pedon.
- It also may include information on any features that differ from the central concept of the soil series for which the described pedon is named (if a series has been defined).

- The description of a body of soil in the field, whether an entire pedon or a soil profile within it, should record the kinds of horizons or layers, their depth and thickness, and the properties of each.
- Generally, external features, such as slope, surface stoniness, erosion, and vegetation, are observed for the area around the pedon, which is considered to be part of the same soil body. Internal features, such as color, texture, and structure, are observed from the study of the pedon.

Observing Pedons

- In order to observe a pedon fully, including soil structure (size and kind), horizon boundary topography, and short-range variability in horizon thickness, a pit exposing a vertical face approximately 1 meter across to an appropriate depth is adequate for most soils.
- Excavations associated with roads, railways, gravel pits, and other soil disturbances provide easy access for studying soils.
- Old exposures, however, must be used cautiously.
- In these areas, the soils can dry out or freeze and thaw from both the surface and the sides.
- In addition, the soil structure may be more pronounced than is typical, salts may have accumulated near the edges of exposures or been removed by seepage, plinthite may have irreversibly hardened to ironstone, or other changes may have taken place.

Figure 1: A shallow soil pit with a face that has been cleaned and prepared for describing the soil profile. This soil (a Fibristel in Alaska) has been dug to the depth of permafrost (about 40 cm).
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- For hand- or backhoe-dug pits, care must be taken to ensure that the pit conforms to safety regulations.
- Loose sandy soils and wet soils are particularly susceptible to cave-ins.
- After the sides of the pit are cleaned of all loose material disturbed by digging, the exposed vertical faces are examined, typically starting at the top and working downward, to identify significant changes in properties.
- Boundaries between layers are marked on the face of the pit, and the layers are identified and described.
- Photographs should be taken after the layers have been identified but before the vertical section is disturbed in the description-writing process.
- An estimation of the volume of stones or other features also is done before the layers are disturbed.

- If bulk samples are to be collected for laboratory analysis, it generally is best to begin with the bottom layer and work upward.
- This prevents material from the upper layers falling onto the face of lower layers before they have been sampled.
- A horizontal view of each horizon is useful.
- This exposes structural units that otherwise may not be readily observable from the vertical pit face.
- Patterns of color within structural units, variations of particle size from the outside to the inside of structural units, and the pattern in which roots penetrate structural units are commonly seen more clearly in a horizontal section.

Figure 2: A horizontal view (looking down) of a fragipan from a soil (a Fragiudalf) in Tennessee.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

Measuring Depth to and Thickness of Horizons and Layers

Soil Surface

- When describing soil profiles, depth is measured from the soil surface.
- Generally, the soil surface is the top of the mineral soil.
- For soils with an O horizon (Oi, Oe, or Oa), it is the top of the O horizon.
- Fresh leaf or needle fall that has not undergone observable decomposition is excluded from the concept of an O horizon and may be described separately as a surface feature.
- Profile measurements begin below any fresh leaf or needle fall.

- For soils that have a cover of 80 percent or more rock or pararock fragments (as in some areas of rubbly colluvial materials), the top of the soil is considered the mean height of the tops of the rock or pararock fragments.
- Depth measurements are taken from this height.
- It is important to note that, when measuring depth and thickness for taxonomic purposes, the "mineral soil surface" is commonly specified as the datum to use in measurements.
- This essentially excludes any overlying O horizon and is therefore not synonymous with the soil surface as defined here for making soil descriptions.

Depth Measurements

- The depth to a horizon or layer boundary commonly differs within short distances, even within a pedon.
- The part of the pedon that is typical or most common is described. In the soil description, the horizon or layer designation is listed, followed by the values that represent the depths from the soil surface to the upper and lower boundaries (e.g., Bt1 - 8 to 20 cm).
- The depth to the lower boundary of a horizon or layer is the depth to the upper boundary of the horizon or layer beneath it.
- Variation in the depths of the boundaries is recorded in the description of the horizon or layer.
- The depth limits of the deepest horizon or layer described include only that part actually seen.

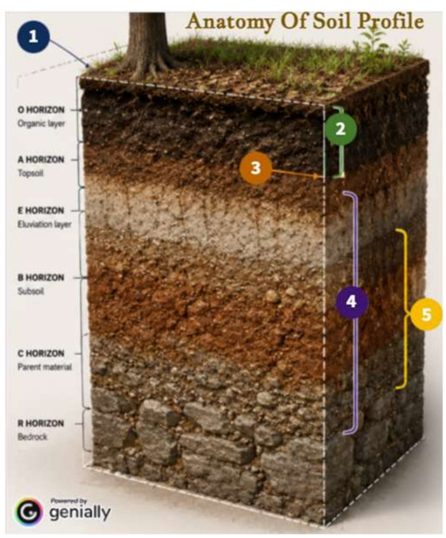
- In some soils, the variations in depths to boundaries are so complex that the usual terms used to describe the boundary topography are inadequate.
- These variations are described separately, e.g., "depth to the lower boundary is mainly 30 to 40 cm, but tongues extend to depths of 60 to 80 cm."
- The lower boundary of a horizon or layer and the upper boundary of the horizon or layer below share a common irregularity.

Thickness Measurements

- The thickness of each horizon or layer is the vertical distance between the upper and lower boundaries.
- Overall thickness may vary within a pedon, and this variation should be noted in the description.
- A range in thickness may be given, e.g., "thickness ranges from 20 to 30 cm."
- This range is not calculated from the range of upper and lower boundary depths.
- Instead, the range is calculated from evaluations across the exposure at different lateral points.
- For example, the upper boundary of a horizon may range in depth from 25 to 45 cm and the lower boundary from 50 to 75 cm.
- Taking the extremes of these two ranges, it is incorrect to conclude that the horizon thickness ranges from as little as 5 cm to as much as 50 cm when in fact it may be 20 to 30 cm in the field.

Designations for Horizons and Layers

- Soils vary widely in the degree to which horizons are expressed.
- Relatively fresh parent materials, such as recent deposits of alluvium, eolian sands, or mantles of volcanic ash, may have no recognizable genetic horizons but may have distinct layers that reflect different modes of deposition.
- As soil formation proceeds, horizons in their early stages may be detected only by very careful examination.
- As horizons increase in age, they generally are more easily identified in the field.
- However, only one or two different horizons may be readily apparent in some very old, deeply weathered soils in tropical areas where annual precipitation is high.
- This section provides the standard nomenclature and definitions for a system used to assign symbols to soil horizons and layers.



Background and Concepts for Use of Designations

- Different kinds of layers are identified by different symbols.
- Designations are provided for layers that have been changed by soil formation and for those that have not.
- Each horizon designation indicates either that the original material has been changed in certain ways or that there has been little or no change.
- The designation is assigned after comparison of the observed properties of the layer with properties inferred for the material before it was affected by soil formation.
- The processes that have caused the change need not be known; properties of soils relative to those of an estimated parent material are the criteria for judgment.
- The parent material inferred for the horizon in question, not the material below the solum, is used as the basis of comparison.
- The inferred parent material commonly is very similar to, or the same as, the soil material below the solum.

- Designations show the describer's interpretations of genetic relationships among the layers within a soil.
- Layers do not need to be identified by symbols in order to make a good description, but the usefulness of soil descriptions is greatly enhanced by the proper use of designations.
- The designations provide a sort of shorthand nomenclature conveying the important properties observed by the person describing the soil as well as the genetic inferences made by that person regarding the formation of the soil.
- The definitions of the symbols provided below are generally more qualitative than quantitative.
- There is a small degree of subjectivity that allows some freedom for the describer to convey their theory of how the soil formed.
- There may be a certain level of inconsistency in the way different describers label the horizons of the same profile.
- For example, one describer may label a horizon "C" while another may label it "CB" or one may record a subtle lithologic discontinuity that another person does not observe.

- Designations are not substitutes for descriptions.
- If both designations and adequate descriptions of a soil are provided, the reader has the interpretation made by the person who described the soil and also the evidence on which the interpretation was based.
- Genetic horizons are not equivalent to the diagnostic horizons of Soil Taxonomy.
- Designations of genetic horizons express a qualitative judgment about the kind of changes that are believed to have taken place.
- Diagnostic horizons are quantitatively defined features used to differentiate taxa.
- Changes implied by genetic horizon designations may not be large enough to justify recognition of diagnostic criteria.
- For example, the designation “Bt” does not always indicate an argillic horizon.
- Furthermore, the diagnostic horizons may not be coextensive with genetic horizons.

Basic System of Horizon and Layer Designations

- Four kinds of symbols are used in various combinations to designate horizons and layers:
  - Capital letters: Used to designate the master horizons and layers.
  - Lowercase letters: Used as suffixes to indicate specific characteristics of master horizons and layers.
  - Numbers: Used both as suffixes to indicate vertical subdivisions within a horizon or layer and as prefixes to indicate discontinuities.
  - Special symbols: Used to indicate layers formed in human-transported material or sequences of horizons having otherwise identical designations.

Master Horizons and Layers

- The capital letters O, L, V, A, E, B, C, R, M, and W represent the master horizons and layers of soils.
- These letters are the base symbols to which other characters are added to complete the designations.
- Most horizons and layers have a designation using one capital letter symbol; some have two.

O Horizons or Layers

- O horizons or layers are dominated by organic soil materials.
- Some are saturated with water for long periods; some were once saturated but are now artificially drained; and others have never been saturated.
- Some O horizons or layers consist of slightly decomposed to highly decomposed litter (such as leaves, needles, twigs, moss, and lichens) that was deposited on the surface of either mineral or organic soils.
- Others consist of organic materials that were deposited under saturated conditions and have decomposed to varying stages.
- The mineral fraction of such material constitutes only a small percentage of the volume of the material and generally much less than half of its weight.
- Some soils consist entirely of materials designated as O horizons or layers.

- An O horizon or layer may be at the surface of a mineral soil or, if buried, at any depth below the surface.
- A horizon formed by illuviation of organic material into a mineral subsoil is not an O horizon, although some horizons that formed in this manner contain a large amount of organic matter.
- Horizons or layers composed of limnic materials are not designated as O horizons.

L Horizons or Layers

- L horizons or layers include both organic and mineral limnic materials that were either:
  - 1. Deposited in water by precipitation or through the actions of aquatic organisms, such as algae and diatoms; or
  - 2. Derived from underwater and floating aquatic plants and subsequently modified by aquatic animals.
- L horizons or layers include coprogenous earth (sedimentary peat), diatomaceous earth, and marl.
- They are described only for Histosols (decomposed plant material) and not for mineral soils.
- They have only the following suffixes: co, di, or ma (described below).
- They do not have the subordinate distinctions of the other master horizons and layers.

V Horizons

- V horizons are mineral horizons that formed at the soil surface or below a layer of rock fragments (e.g., desert pavement), a physical or biological crust, or recently deposited eolian material.
- They are characterized by the predominance of vesicular pores and have platy, prismatic, or columnar structure.

- Porosity in a V horizon may include vughs and collapsed vesicles in addition to the spherical vesicular pores.
- V horizons formed in eolian material but may be underlain by soil horizons that formed in residuum, alluvium, or other transported materials.
- Because of their eolian origin, they are typically enriched in particle-size fractions ranging from silt through fine sand.
- Rarely, the V horizon is massive rather than structured.
- The structural arrangement of particles and vesicular porosity differentiates this horizon from the loose, unaltered eolian deposits that may occur above it.
- Underlying B horizons commonly have redder hues than the V horizon and lack vesicular pores.

- Transitional and combination horizons with V horizon material occur in certain circumstances.
- Although uncommon, an AV or VA horizon may occur.
- It is both enriched in organic matter and contains vesicular pores.
- BV or VB horizons may indicate vesicular horizons that contain clay or carbonate coatings, or other properties of the underlying B horizon.
- EV or VE transitional horizons may also occur, especially in sodic soils.
- Combination horizons of the V horizon with A, B, or E horizons may occur in bioturbated zones, such as shrub islands or areas where surface cover associated with the vesicular horizon (e.g., desert pavement) is patchy.
- Vesicular pores have been observed to reform quickly after physical disruption.

A Horizons

- A horizons are mineral horizons that formed at the soil surface or below an O horizon.
- They exhibit obliteration of all or much of any original rock structure and show one or both of the following:
  - 1. An accumulation of humified organic matter closely mixed with the mineral fraction and not dominated by properties characteristic of V, E, or B horizons; and/or
  - 2. Properties resulting from cultivation, pasturing, or similar kinds of disturbance.
- If a surface horizon has properties of both A and E horizons but the feature emphasized is an accumulation of humified organic matter, it is designated as an A horizon.
- Recent alluvial or eolian deposits that retain most of the original rock structure are not considered to be A horizons unless they are cultivated.

E Horizons

- E horizons are mineral horizons in which the main feature is the eluvial loss of silicate clay, iron, aluminum, or some combination of these that leaves a concentration of sand and silt particles.
- They exhibit obliteration of all or much of the original rock structure.

- An E horizon is commonly differentiated from an underlying B horizon in the same sequum by a color of higher value or lower chroma (or both), by coarser texture, or by a combination of these properties.
- In some soils the color of the E horizon is that of the sand and silt particles, but in many soils coatings of iron oxides or other compounds mask the color of the primary particles.
- An E horizon is most commonly differentiated from an overlying A horizon by its lighter color.
- It generally contains less organic matter than the A horizon.
- It is commonly near the soil surface, below an O, V, or A horizon, and above a B horizon.
- However, the symbol E can be used for eluvial horizons that are at the soil surface, are within or between parts of the B horizon, or extend to depths greater than those of normal observation, if the horizons have resulted from pedogenic processes.

B Horizons

- B horizons are mineral horizons that typically formed below an A, V, E, or O horizon.
- They exhibit obliteration of all or much of the original rock structure and show one or more of the following as evidence of pedogenesis:
  - 1. Illuvial concentration of silicate clay, iron, aluminum, humus, sesquioxides, carbonates, gypsum, salts more soluble than gypsum, or silica, alone or in combination;
  - 2. Evidence of the removal, addition, or transformation of carbonates, anhydrite, and/or gypsum;
  - 3. Residual concentration of oxides, sesquioxides, and silicate clay, alone or in combination;
  - 4. Coatings of sesquioxides that make the horizon color conspicuously lower in value, higher in chroma, or redder in hue than overlying and underlying horizons, without apparent illuviation of iron;
  - 5. Alteration that forms silicate clay or liberates oxides, or both, and that forms pedogenic structure if volume changes accompany changes in moisture content;
  - 6. Brittleness; or
  - 7. Strong gleying when accompanied by other evidence of pedogenic change.

- All of the different kinds of B horizons are, or originally were, subsurface horizons.
- B horizons include horizons (cemented or not cemented) with illuvial concentrations of carbonates, gypsum, or silica that are the result of pedogenic processes.
- They are contiguous to other genetic horizons and brittle layers that show other evidence of alteration, such as prismatic structure or illuvial accumulation of clay.
- B horizons do not include layers in which clay films coat rock fragments or cover finely stratified unconsolidated sediments, regardless of whether the films formed in place or by illuviation; layers into which carbonates have been illuviated but that are not contiguous to an overlying genetic horizon; and layers with strong gleying but no other pedogenic changes.

C Horizons or Layers

- C horizons or layers are mineral horizons or layers, excluding strongly cemented and harder bedrock, that are little affected by pedogenic processes and lack properties of O, A, V, E, B, and L horizons.
- Their material may be either like or unlike that from which the solum presumably formed.
- The C horizon may have been modified, even if there is no evidence of pedogenesis.

- Included as C layers (and typically designated Cr) are sediment, saprolite, bedrock, and other geologic materials that are moderately cemented or less cemented.
- The excavation difficulty of these materials commonly is low or moderate.
- In descriptions of soils that formed in material that is already highly weathered, if this material does not meet the requirements of an A, V, E, or B horizon, it is designated by the letter C.
- Changes are not considered pedogenic if they are not related to the overlying horizons.
- Some layers that have accumulations of silica, carbonates, gypsum, or more soluble salts are included in C horizons, even if cemented.
- However, if a cemented layer formed through pedogenic processes, rather than geologic processes (e.g., lithification), it is considered a B horizon.

R Layers

- R layers consist of strongly cemented to indurated bedrock.
- Granite, basalt, quartzite, limestone, and sandstone are examples of bedrock that commonly is cemented enough to be designated by the letter R.
- The excavation difficulty of these layers commonly exceeds high.
- The R layer is sufficiently coherent when moist to make hand-digging with a spade impractical, although it may be chipped or scraped.
- Some R layers can be ripped with heavy power equipment.
- The bedrock may have fractures, but these are generally too few or too widely spaced to allow root penetration.
- The fractures may be coated or filled with clay or other material.

M Layers

- M layers are root-limiting layers beneath the soil surface consisting of nearly continuous, horizontally oriented, human-manufactured materials.
- Examples of materials designated by the letter M include geotextile liners, asphalt, concrete, rubber, and plastic, if they occur as continuous, horizontal layers.

W Layers

- W layers are used to identify water layers within or beneath the soil.
- They are not merely layers of saturated soil material but rather zones of water between soil layers.
- The water layer is designated "Wf " if it is permanently frozen (as in a glacic horizon) and "W" if it is not permanently frozen (as in a floating bog).
- The designations W and Wf are not used for shallow water, ice, or snow above the soil surface.

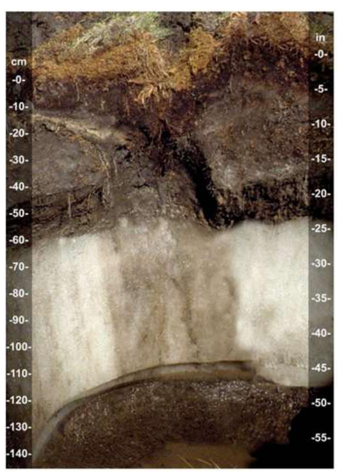


Figure 3: A soil (a Glacistel in Alaska) with a permanently frozen ice layer (designated "Wf") between depths of 60 and 130 cm.

(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

Transitional and Combination Horizons

- In some cases a single master horizon designation does not adequately convey information about the layer, such as where the horizon transitions to another layer or where it contains distinct parts from two kinds of master horizons.

Transitional Horizons

- Transitional horizons are dominated by properties of one master horizon but have subordinate properties of another.
- They are designated by two capital-letter symbols, e.g., AB, EB, BE, or BC.
- The first letter indicates the horizon whose properties dominate the transitional horizon.
- An AB horizon, for example, has characteristics of both an overlying A horizon and an underlying B horizon, but it is more like the A horizon than the B.
- In some cases, a horizon can be designated as transitional even if one of the master horizons to which it transitions is not present.
- For example, a BE horizon recognized in a truncated soil has properties similar to those of a BE horizon in a soil from which the overlying E horizon has not been removed by erosion.
- A BC horizon may be recognized even if no underlying C horizon is present: it transitions to assumed parent materials.

Combination Horizons

- Combination horizons have two distinct parts that have recognizable properties of the two kinds of master horizons.
- They are designated by two capital-letter symbols (master horizons) separated by a virgule (/), e.g., E/B, B/E, or B/C.
- Most of the individual parts of one horizon component are surrounded by the other.
- The designation may be used even when horizons similar to one or both of the components are not present, provided that the separate components can be recognized in the combination horizon.
- The first letter indicates the horizon with the greater volume.

- Because single sets of designators do not cover all situations, some improvising may be necessary.
- For example, Lamellic Udipsamments have lamellae that are separated from each other by eluvial layers.
- It is generally not practical to describe each lamella and eluvial layer as a separate horizon, so the horizons can be combined and the components described separately.
- The horizon with several lamellae and eluvial layers can be designated as an "E and Bt" horizon.
- The complete horizon sequence for these soils could be: Ap-Bw-E and Bt1-E and Bt2-C.

Suffix Symbols

- Lowercase letters are used as suffixes to designate specific subordinate distinctions within master horizons and layers.
- The term "accumulation," which is used in many of the suffix definitions, indicates that the horizon has more of the material in question than is presumed to have been present in the parent material.
- The use of a suffix symbol is not restricted only to those horizons that meet certain criteria for diagnostic horizons and other criteria as defined in Soil Taxonomy.
- If there is any evidence of accumulation, a suffix (or suffixes) can be used.

- The suffix symbols and their meanings follow:
  - a: Highly decomposed organic material
    - This symbol is used with O horizons to indicate the most highly decomposed organic materials, which have a fiber content of less than 17 percent (by volume) after rubbing.
  - b: Buried genetic horizon
    - This symbol indicates identifiable buried horizons with major genetic features that developed before burial.
    - Genetic horizons may or may not have formed in the overlying material, which may be either like or unlike the assumed parent material of the buried horizon.
    - This symbol is not used to separate horizons composed of organic soil material (that are forming at the soil surface) from underlying horizons composed of mineral soil material.
    - It may be used in organic soils, but only if they are buried by mineral soil materials.

- c: Concretions or nodules
  - This symbol indicates a significant accumulation of concretions or nodules.
  - Cementation is required.
  - The cementing agent commonly is iron, aluminum, manganese, or titanium.
  - It cannot be silica, dolomite, calcite, gypsum, anhydrite, or soluble salts.
- co: Coprogenous earth
  - This symbol, used only with L horizons, indicates a limnic layer of coprogenous earth (sedimentary peat).

- d: Physical root restriction
  - This symbol indicates non-cemented, root-restricting layers in naturally occurring or human-made sediments or materials.
  - Examples of natural layers are dense till and some non-cemented shales and siltstones.
  - Examples of human-made dense layers are plowpans and mechanically compacted zones in human-transported material.
- di: Diatomaceous earth
  - This symbol, used only with L horizons, indicates a limnic layer of diatomaceous earth.

- e: Organic material of intermediate decomposition
  - This symbol is used with O horizons to indicate organic materials of intermediate decomposition.
  - The fiber content of these materials is 17 to less than 40 percent (by volume) after rubbing.
- f: Frozen soil or water
  - This symbol indicates that a horizon or layer contains permanent ice.
  - It is not used for seasonally frozen layers or for dry permafrost.

- ff: Dry permafrost
  - This symbol indicates a horizon or layer that is continually colder than 0 °C and does not contain enough ice to be cemented by ice.
  - It is not used for horizons or layers that have a temperature warmer than 0 °C at some time during the year.
- g: Strong gleying
  - This symbol indicates either that iron has been reduced and removed during soil formation or that saturation with stagnant water has preserved iron in a reduced state.
  - Most of the affected layers have chroma of 2 or less, and many have redox concentrations.
  - The low chroma can represent either the color of reduced iron or the color of the uncoated sand and silt particles from which iron has been removed.
  - The symbol is not used for soil materials of low chroma that have no history of wetness, such as some shales or E horizons.
  - If it is used with B horizons, pedogenic change (e.g., soil structure) in addition to gleying is implied.
  - If no other pedogenic change besides gleying has taken place, the horizon is designated "Cg."

- h: Illuvial accumulation of organic matter
  - This symbol is used with B horizons to indicate the accumulation of illuvial, amorphous, dispersible complexes of organic matter and sesquioxides.
  - The sesquioxide component is dominated by aluminum and is present only in very small quantities.
  - The organo-sesquioxide material coats sand and silt particles.
  - In some horizons these coatings have coalesced, filled pores, and cemented the horizon.
  - The symbol h is also used in combination with the symbol s (e.g., Bhs) if the amount of the sesquioxide component is significant but the value and chroma, moist, of the horizon are 3 or less.
- i: Slightly decomposed organic material
  - This symbol is used with O horizons to indicate the least decomposed of the organic materials.
  - The fiber content of these materials is 40 percent or more (by volume) after rubbing.

- j: Accumulation of jarosite
  - This symbol indicates an accumulation of jarosite, which is a potassium (ferric) iron hydroxy sulfate mineral, $KFe_3(SO_4)_2(OH)_6$.
  - Jarosite is commonly the product of pyrite that has been exposed to an oxidizing environment.
  - It has hue of 2.5Y or yellower and normally has chroma of 6 or more, although chroma as low as 3 or 4 has been reported.
  - It forms in preference to iron (hydr)oxides in active acid sulfate soils at pH of 3.5 or less and can be stable for long periods of time in post-active acid sulfate soils with higher pH.

- jj: Evidence of cryoturbation
  - This symbol indicates evidence of cryoturbation, which includes irregular and broken horizon boundaries, sorted rock fragments, and organic soil materials occurring as bodies and broken layers within and/or between mineral soil layers.
  - The organic bodies and layers are most commonly at the contact between an active layer and the permafrost.
- k: Accumulation of secondary carbonates
  - This symbol indicates an accumulation of visible pedogenic calcium carbonate (less than 50 percent, by volume).
  - Carbonate accumulations occur as carbonate filaments, coatings, masses, nodules, disseminated carbonate, or other forms.

- kk: Engulfment of horizon by secondary carbonates
  - This symbol indicates major accumulations of pedogenic calcium carbonate.
  - It is used when the soil fabric is plugged with fine grained pedogenic carbonate (50 percent or more, by volume) that occurs as an essentially continuous medium.
  - It corresponds to the Stage III (or higher) plugged horizon of the carbonate morphogenetic stages.

- m: Pedogenic cementation
  - This symbol indicates continuous or nearly continuous pedogenic cementation.
  - It is used only for horizons that are more than 90 percent cemented but may be fractured.
  - The cemented layer is physically root-restrictive.
  - The predominant cementing agent (or the two dominant ones) can be indicated by letter suffixes, singly or in pairs.
  - The horizon suffix kkm (and the less commonly used km) indicates cementation by carbonates; qm, cementation by silica; sm, cementation by iron; yym, cementation by gypsum; kqm, cementation by carbonates and silica; and zm, cementation by salts more soluble than gypsum.
  - The symbol m is not used for permanently frozen layers impregnated by ice.

- ma: Marl
  - This symbol, used only with L horizons, indicates a limnic layer of marl.
- n: Accumulation of sodium
  - This symbol indicates an accumulation of exchangeable sodium.
- o: Residual accumulation of sesquioxides
  - This symbol indicates a residual accumulation of sesquioxides.
- p: Tillage or other disturbance
  - This symbol indicates disturbance of a horizon by mechanical means, pasturing, or similar uses.
  - A disturbed organic horizon is designated “Op.”
  - A disturbed mineral horizon is designated “Ap” even if it is clearly a former E, B, or C horizon.

- q: Accumulation of silica
  - This symbol indicates an accumulation of secondary silica.
- r: Weathered or soft bedrock
  - This symbol is used with C horizons to indicate layers of bedrock that are moderately cemented or less cemented.
  - Examples are weathered igneous rock and partly consolidated sandstone, siltstone, or shale.
  - The excavation difficulty is low to high.

- s: Illuvial accumulation of sesquioxides and organic matter
  - This symbol is used with B horizons to indicate an accumulation of illuvial, amorphous, dispersible complexes of organic matter and sesquioxides, if both the organic matter and sesquioxide components are significant and if either the value or chroma, moist, of the horizon is 4 or more.
  - The symbol is also used in combination with h (e.g., Bhs) if both the organic matter and sesquioxide components are significant and if the value and chroma, moist, are 3 or less.

- se: Presence of sulfides
  - This symbol indicates the presence of sulfides in mineral or organic horizons.
  - Horizons with sulfides typically have dark colors (e.g., value of 4 or less, chroma of 2 or less).
  - These horizons typically form in soils associated with coastal environments that are permanently saturated or submerged (i.e., tidal marshes or estuaries).
  - Soil materials which have sulfidization actively occurring emanate hydrogen sulfide gas, which is detectable by its odor.
  - Sulfides may also occur in upland environments that have a source of sulfur.
  - Soils in such environments are commonly of geologic origin and may not have a hydrogen sulfide odor.
  - Examples include soils that formed in parent materials derived from coal deposits, such as lignite, or soils that formed in coastal plain deposits, such as glauconite, that have not been oxidized because of thick layers of overburden.

- ss: Presence of slickensides
  - This symbol indicates the presence of pedogenic slickensides.
  - Slickensides result directly from the swelling of clay minerals and shear failure, commonly at angles of 20 to 60 degrees above horizontal.
  - They are indicators that other vertic characteristics, such as wedge-shaped peds and surface cracks, may be present.

- t: Accumulation of silicate clay
  - This symbol indicates an accumulation of silicate clay that either has formed within a horizon and subsequently has been translocated within the horizon or that has been moved into the horizon by illuviation, or both.
  - At least some part of the horizon shows evidence of clay accumulation, either as coatings on surfaces of peds or in pores, as lamellae, or as bridges between mineral grains.

- u: Presence of human-manufactured materials (artifacts)
  - This symbol indicates the presence of objects or materials that have been created or modified by humans, typically for a practical purpose in habitation, manufacturing, excavation, or construction activities.
  - Examples of artifacts are bitumen (asphalt), boiler slag, bottom ash, brick, cardboard, carpet, cloth, coal combustion by-products, concrete (detached pieces), debitage (i.e., stone tool flakes), fly ash, glass, metal, paper, plasterboard, plastic, potsherd, rubber, treated wood, and untreated wood products.

- v: Plinthite
  - This symbol is used to indicate the presence of iron-rich, humus-poor, reddish material that is firm or very firm when moist and is less than strongly cemented.
  - Plinthite hardens irreversibly when exposed to the atmosphere and to repeated wetting and drying.
- w: Development of color or structure
  - This symbol is used only with B horizons to indicate the development of color or structure, or both, with little or no apparent illuvial accumulation of material.
  - Note: It is not used to indicate a transitional horizon.

- x: Fragipan character
  - This symbol indicates a genetically developed layer that has a combination of firmness and brittleness and commonly a higher bulk density than adjacent layers.
  - Some part of the layer is physically root-restrictive.
- y: Accumulation of gypsum
  - This symbol indicates an accumulation of gypsum.
  - It is used when the horizon fabric is dominated by soil particles or minerals other than gypsum.
  - Gypsum is present in amounts that do not significantly obscure or disrupt other features of the horizon.
  - This symbol is also used to indicate the presence of anhydrite.

- yy: Dominance of horizon by gypsum
  - This symbol indicates a horizon that is dominated by the presence of gypsum.
  - The gypsum content may be due to an accumulation of secondary gypsum, the transformation of primary gypsum inherited from parent material, or other processes.
  - This symbol is used when the horizon fabric has such an abundance of gypsum (generally 50 percent or more, by volume) that pedogenic and/or lithologic features are obscured or disrupted by growth of gypsum crystals.
  - Horizons that have this suffix typically are highly whitened (e.g., value of 7 through 9.5 and chroma of 4 or less).
  - This symbol is also used to connote the presence of anhydrite.
- z: Accumulation of salts more soluble than gypsum
  - This symbol indicates an accumulation of salts that are more soluble than gypsum.

Conventions for Using Horizon Designation Symbols

- The following guidelines can be used in assigning horizon designation symbols to soil horizons and layers.

Letter Suffixes

- Many master horizons and layers that are symbolized by a single capital letter can have one or more lowercase-letter suffixes.
- The following rules apply:
  - 1. Letter suffixes directly follow the capital letter of the master horizon or layer, or the prime symbol, if used.
  - 2. More than three suffixes are rarely used.
  - 3. If more than one suffix is needed, the following letters (if used) are written first: a, d, e, h, i, r, s, t, and w.
    - None of these letters are used in combination for a single horizon, except to designate a Bhs horizon or Crt layer.
  - 4. If more than one suffix is needed and the horizon is not buried, the following symbols, if used, are written last: c, f, g, m, v, and x.
    - Examples are Bjc and Bkkm. If any of these suffixes are used together in the same horizon, symbols c and g are written last (e.g., Btvg), with one exception.
    - If the symbol f (frozen soil or water) is used together with any of the other symbols in this rule, it is written last, e.g., Cdgf.
  - 5. If a genetic horizon is buried, the suffix b is written last, e.g., Oab.
  - 6. Suffix symbols h, s, and w are not used with g, k, kk, n, o, q, y, yy, or z.
  - 7. If the above rules do not apply to certain suffixes, such as k, kk, q, y, or yy, the suffixes may be listed together in order of assumed dominance or alphabetically if dominance is not a concern.

- A B horizon that has a significant accumulation of clay and also shows development of color or structure, or both, is designated "Bt" (suffix symbol t has precedence over symbols w, s, and h).
- A B horizon that is gleyed or that has accumulations of carbonates, sodium, silica, gypsum, salts more soluble than gypsum, or residual accumulations of sesquioxides carries the appropriate symbol: g, k, kk, n, q, y, yy, z, or o.
- If illuvial clay is also present, the symbol t precedes the other symbol, e.g., Bto.

Vertical Subdivisions

- Commonly, a horizon or layer designated by a single letter or a combination of letters has to be subdivided.
- For this purpose, numbers are added to the letters of the horizon designation.
- These numbers follow all the letters.
- Within a sequence of C horizons, for example, successive layers may be designated C1, C2, C3, etc.
- If the lower horizons are strongly gleyed and the upper horizons are not strongly gleyed, they may be designated C1-C2-Cg1-Cg2 or C-Cg1-Cg2-R.

- These conventions apply regardless of the purpose of the subdivision.
- In many soils a horizon that could be identified by a single set of letters is subdivided to recognize differences in morphological features, such as structure, color, or texture.
- These divisions are numbered consecutively, but the numbering starts again at 1 when any letter of the horizon symbol changes, e.g., Bt1-Bt2-Btk1-Btk2 (not Bt1-Bt2-Btk3-Btk4).
- The numbering of vertical subdivisions within consecutive horizons is not interrupted at a discontinuity (indicated by a numerical prefix) if the same letter combination is used in both materials, e.g., Bs1-Bs2-2Bs3- 2Bs4 (not Bs1-Bs2-2Bs1-2Bs2).

- During sampling for laboratory analyses, thick soil horizons are sometimes subdivided even though differences in morphology are not evident in the field.
- These subdivisions are identified by numbers that follow the respective horizon designations.
- For example, four subdivisions of a Bt horizon sampled by 10-cm increments are designated Bt1, Bt2, Bt3, and Bt4.
- If the horizon has already been subdivided because of differences in morphological features, the set of numbers that identifies the additional sampling subdivisions follows the first number.
- For example, three subdivisions of a Bt2 horizon sampled by 10-cm increments are designated Bt21, Bt22, and Bt23.
- The descriptions for each of these sampling subdivisions can be the same, and a statement indicating that the horizon has been subdivided only for sampling purposes can be added.

Discontinuities

- Numbers are used as prefixes to horizon designations (specifically, A, V, E, B, C, and R) to indicate discontinuities in mineral soils.
- These prefixes are distinct from the numbers that are used as suffixes denoting vertical subdivisions.

- A discontinuity that can be identified by a number prefix is a significant change in particle-size distribution or mineralogy that indicates a difference in the parent material from which the horizons have formed and/or a significant difference in age, unless the difference in age is indicated by the suffix b.
- Symbols that identify discontinuities are used only when they can contribute substantially to an understanding of the relationships among horizons.
- The stratification common to soils that formed in alluvium is not designated as a discontinuity, unless particle-size distribution differs markedly from layer to layer (i.e., particle-size classes are strongly contrasting) even though genetic horizons may have formed in the contrasting layers.

- If a soil formed entirely in one kind of material, the whole profile is understood to be material 1 and the number prefix is omitted from the symbol.
- Similarly, the uppermost material in a profile consisting of two or more contrasting materials is understood to be material 1 and the number is omitted.
- Numbering starts with the second layer of contrasting material, which is designated 2.
- Underlying contrasting layers are numbered consecutively.

- Even when the material of a layer below material 2 is similar to material 1, it is designated 3 in the sequence; the numbers indicate a change in materials, not types of material.
- Where two or more consecutive horizons have formed in the same kind of material, the same prefix number indicating the discontinuity is applied to all the designations of horizons in that material, for example, Ap-E-Bt1-2Bt2- 2Bt3-2BC.
- The suffix numbers designating vertical subdivisions of the Bt horizon continue in consecutive order across the discontinuity.
- However, vertical subdivisions do not continue across lithologic discontinuities if the horizons are not consecutive or contiguous to each other.
- If other horizons intervene, another vertical numbering sequence begins for the lower horizons, for example, A-C1-C2-2Bw1-2Bw2-2C1-2C2.

- If an R layer is below a soil that formed in residuum and if it is similar to the material from which the soil developed, the number prefix is not used.
- The prefix is used, however, if it is thought that the R layer would weather to material unlike that in the solum, e.g., A-Bt-C-2R or A-Bt-2R.
- If part of the solum has formed in residuum, the symbol R is given the appropriate prefix, for example, Ap-Bt1-2Bt2-2Bt3-2C1-2C2-2R.

- A buried genetic horizon (designated by the suffix b) requires special consideration.
- It is obviously not in the same deposit as the overlying horizons.
- Some buried horizons, however, formed in material that is lithologically like the overlying deposit.
- In this case, a prefix is not used to distinguish material of the buried horizon.

- If the material in which a horizon of a buried soil formed is lithologically unlike the overlying material, the discontinuity is indicated by a number prefix and the symbol for the buried horizon also is used, for example, Ap-Bt1-Bt2- BC-C-2ABb-2Btb1-2Btb2-2C.
- Discontinuities between different kinds of layers in organic soils are not identified.
- In most cases, such differences are identified by letter suffixes if the different layers are organic materials (e.g., Oe vs. Oa) or by the master horizon symbol if the different layers are mineral or limnic materials (e.g., Oa vs. Ldi).

The Prime Symbol

- If two or more horizons with identical number prefixes and letter combinations are separated by one or more horizons with a different horizon designation, identical letter and number symbols can be used for those horizons with the same characteristics.
- For example, the sequence A-E-Bt-E-Btx-C identifies a soil that has two E horizons.
- To emphasize this characteristic, the prime symbol (´) is added after the symbol of the lower of the two horizons that have identical designations, e.g., A-E-BtE´-Btx-C.
- The prime symbol is placed after the master horizon symbol and before the suffix letter symbol or symbols (if used), for example, B´t.

- The prime symbol is not used unless all letter and number prefixes are completely identical.
- The sequence A-Bt1-Bt2-2E-2Bt1-2Bt2 is an example.
- Because it has two Bt master horizons of different lithologies, the Bt horizons are not identical and the prime symbol is not needed.
- The prime symbol is used for soils with lithologic discontinuities if horizons have identical designations.
- For example, a soil with the sequence A-C2Bw-2Bc-2B´w-3Bc has two identical 2Bw horizons but two different Bc horizons (2Bc and 3Bc); the prime symbol is used only with the lower 2Bw horizon (2B´w).
- In the rare cases where three layers have identical letter symbols, double prime symbols can be used for the lowest of these horizons, for example, E´´.

- Vertical subdivisions of horizons or layers (number suffixes) are not taken into account when the prime symbol is assigned.
- The sequence A-E-Bt-E´-B´t1-B´t2-B´t3-C is an example.
- These same principles apply in designating layers of organic soils.
- The prime symbol is used only to distinguish two or more horizons that have identical symbols.
- For example, Oi-C-O´i-C´ indicates a soil with two identical Oi and C layers and Oi-C-Oe-C´ indicates a soil with two identical C layers.
- The prime symbol is added to the lower layers to differentiate them from the upper layers.

The Caret Symbol

- The caret symbol (^) is used as a prefix to indicate horizons and layers that formed in human-transported material.
- This material has been moved horizontally onto a pedon from a source area outside of that pedon by purposeful human activity, usually with the aid of machinery or hand tools.
- Number prefixes may be used before the caret symbol to indicate the presence of discontinuities within the human-transported material (e.g., ^Au-^Bwu-^BCu-2^Cu1-2^Cu2) or between the human-transported material and underlying horizons formed in other parent materials (e.g., ^A-^C1-2^C2-3Bwb).

Sample Horizons and Sequences

- The following examples illustrate some common horizon and layer sequences of important soils (subgroup taxa) and the use of numbers to identify vertical subdivisions and discontinuities.
- Transitional horizons, combination horizons, and the use of the prime and caret symbols are also illustrated.

Mineral Soils

- Typic Hapludoll: A1-A2-Bw-BC-C
- Typic Haplustoll: Ap-A-Bw-Bk-Bky1-Bky2-C
- Cumulic Haploxeroll: Ap-A-Ab-C-2C-3C
- Typic Argialboll: Ap-A-E-Bt1-Bt2-BC-C
- Typic Argiaquoll: A-AB-BA-Btg-BCg-Cg
- Alfic Udivitrand: Oi-A-Bw1-Bw2-2E/Bt-2Bt/E1-2Bt/E2-2Btx1- 2Btx2
- Entic Haplorthod: Oi-Oa-E-Bs1-Bs2-BC-C
- Typic Haplorthod: Ap-E-Bhs-Bs-BC-C1-C2
- Typic Fragiudalf: Oi-A-E-BE-Bt1-Bt2-B/E-Btx1-Btx2-C
- Typic Haploxeralf: A1-A2-BAt-2Bt1-2Bt2-2Bt3-2BC-2C

- Glossic Hapludalf: Ap-E-B/E-Bt1-Bt2-C
- Typic Paleudult: A-E-Bt1-Bt2-B/E-B´t1-B´t2-B´t3
- Typic Hapludult: Oi-A1-A2-BA-Bt1-Bt2-BC-C
- Arenic Plinthic Paleudult: Ap-E-Bt-Btc-Btv1-Btv2-BC-C
- Xeric Haplodurid: A-Bw-Bkq-2Bkqm
- Vertic Natrigypsid: A-Btn-Btkn-Bky-2By-2BCy-2Cr
- Typic Calciargid: A-Bt-Btk1-Btk2-C
- Typic Dystrudept: Ap-Bw1-Bw2-C-R
- Typic Fragiudept: Ap-Bw-E-Bx1-Bx2-C
- Typic Endoaquept: Ap-AB-Bg1-Bg2-BCg-Cg
- Typic Haplustert: Ap-A-Bss-BCss-C
- Typic Hapludox: Ap-A/B-Bo1-Bo2-Bo3-Bo4-Bo5
- Typic Udifluvent: Ap-C-Ab-C´
- Glacic Histoturbel: Oi-OA-Bjjg-Wf-Cgf

Organic Soils

- Typic Haplosaprist: Oap-Oa1-Oa2-Oa3-C
- Typic Sphagnofibrist: Oi1-Oi2-Oi3-Oe
- Limnic Haplofibrist: Oi-Lco-O´i1-O´i2-L´co-Oe-C
- Lithic Cryofolist: Oi-Oa-R Typic Hemistel: Oi-Oe-Oef

Human-Altered Soils

- Anthrodensic Ustorthent: ^Ap-^C/B-^Cd-2C
- Anthroportic Udorthent: ^Ap-^Cu-Ab-Btb-C

Subaqueous Soils

- Psammentic Frasiwassents: A1-A2-CA-Cg1-Cg2-Cg3-Cg4
- Thapto-Histic Sulfiwassents: Ase-Cse1-Cse2-Oase1-Oa1-Oa2
- Sulfic Psammowassents: A-Cg1-Cg2-Aseb-C´g-A´seb-C´´g1- C´´g2-C´´g3

Cyclic and Intermittent Horizons and Layers

- Soils with cyclic or intermittent horizons pose special challenges in describing soil profiles.
- The profile of a soil having cyclic horizons exposes layers whose boundaries are near the surface at one point and extend deep into the soil at another.
- The aggregate horizon thickness may be only 50 cm at one place but more than 125 cm at a place 2 meters away.
- The cycle repeats.
- It commonly has considerable variation in both depth and horizontal interval but still has some degree of regularity.
- When the soil is visualized in three dimensions instead of two, some cyclic horizons extend downward in inverted cones.
- The cone of the lower horizon fits around the cone of the horizon above.
- Other cyclic horizons appear wedge-shaped.

- The profile of a soil having an intermittent horizon shows that the horizon extends horizontally for some distance, ends, and reappears again some distance away.
- For example, the horizons of Turbels, which by definition are subject to cryoturbation, are irregular, intermittent, and distorted.
- A B horizon interrupted at intervals by upward extensions of bedrock into the A horizon is another example.
- The distance between places where the horizon is absent is commonly variable but has some degree of regularity.
- It ranges from less than 1 meter to several meters.

- For soils with cyclic or intermittent horizons or layers, a soil profile at one place may be unlike a profile only a few meters away.
- Standardized horizon nomenclature and pedon description forms are not well suited to soil profiles with such variability.
- When describing these types of soils, it is important to make notes on the individual horizons to record the nature of the variations.
- Photographs and diagrams can also be used to convey the information.
- Descriptions of the order of horizontal variation as well as vertical variation within a pedon include the kind of variation, the spacing of cycles or interruptions, and the amplitude of depth variation of cyclic horizons.

Boundaries of Horizons and Layers

- A boundary is a relatively sharp plane-like division or a more gradual transitional layer between two adjoining horizons or layers.
- Most boundaries are zones of transition rather than sharp lines of division.
- Boundaries vary in distinctness and topography.

Distinctness

- Distinctness refers to the thickness of the zone within which the boundary can be located.
- The distinctness of a boundary depends partly on the degree of contrast between the adjacent layers and partly on the thickness of the transitional zone between them.
- Distinctness is defined in terms of thickness of the transitional zone as follows:
    - Very abrupt less than 0.5 cm
    - Abrupt 0.5 to less than 2 cm
    - Clear 2 to less than 5 cm
    - Gradual 5 to less than 15 cm
    - Diffuse 15 cm or more

- Very abrupt boundaries occur at some lithologic discontinuities, such as geogenic deposits or strata (tephras, alluvial strata, etc.).
- They can also occur at the contacts of root-limiting layers.
- Examples are duripans; fragipans; petrocalcic, petrogypsic, and placic horizons; continuous ortstein; and densic, lithic, paralithic, and petroferric contacts.

- Abrupt soil boundaries, such as those between the E and Bt horizons of many soils, are easily determined.
- Some boundaries are not readily seen but can be located by testing the soil above and below the boundary.
- Diffuse boundaries, such as those in many old soils in tropical areas, are very difficult to locate.
- They require time-consuming comparisons of small specimens of soil from various parts of the profile to determine the midpoint of the transitional zone.
- For soils that have nearly uniform properties or that change very gradually as depth increases, horizon boundaries are imposed more or less arbitrarily without clear evidence of differences.

Topography

- Topography refers to the irregularities of the surface that divides the horizons.
- Terms for topography describe the shape of the contact between horizons as seen in a vertical cross-section.
- Even though soil layers are commonly seen in vertical section, they are three-dimensional.
- Terms describing topography of boundaries are:
  - Smooth: The boundary is a plane with few or no irregularities.
  - Wavy: The boundary has undulations in which depressions are wider than they are deep.
  - Irregular: The boundary has pockets that are deeper than they are wide.
  - Broken: One or both of the horizons or layers separated by the boundary are discontinuous and the boundary is interrupted.

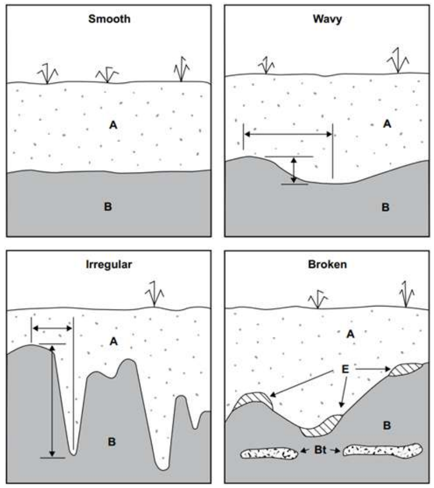
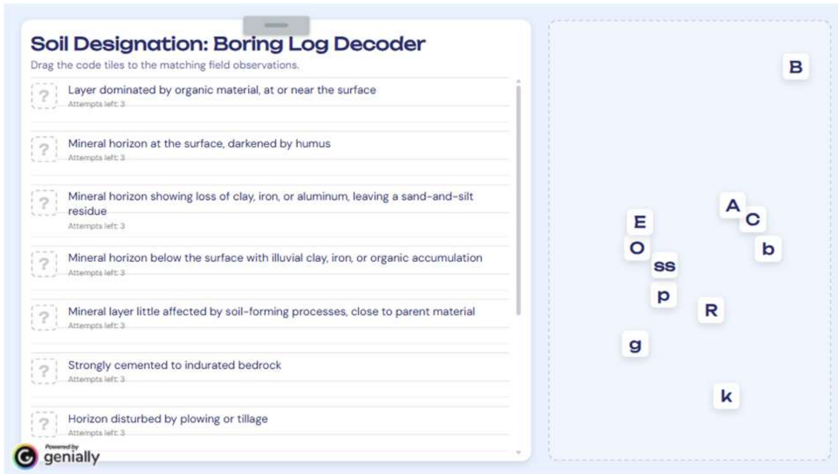


Figure 4: Examples of topography classes for horizon boundaries.

(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

Thickness

- The thickness of the horizon or layer is recorded by entering depths for the upper and lower boundaries.
- For horizons or layers with significant lateral variation in thickness, the average horizon thickness may also be noted.



Near Surface Subzones

Background Information

- In many soils, the morphology of the uppermost few centimeters (generally from less than 1 to about 18 cm) is strongly controlled by antecedent weather and by soil use.
- A soil may be freshly tilled and have a loose surface one day and have a strong crust because of a heavy rain the next day.
- A soil may be highly compacted by livestock and have a firm near surface in one place but have little disturbance to the uppermost few centimeters and be very friable in most other places.
- These affected soils properties are referred to as "use-dependent" or "dynamic."

- The following discussion provides a set of terms for describing subzones of the near surface and, in particular, the near surface of tilled soils.
- The horizon designations or symbols for describing these near surface subzones are limited.
- The suffix d is used for root-restrictive compacted layers; master horizon symbol V may be used to designate some layers with a dominance of vesicular pores.
- Surface horizons can be subdivided using standard horizon designations to record the subzones.
- An example horizon sequence could include Ap1 (a mechanically bulked subzone), Ap2 (a water-compacted subzone), and Bd (a mechanically compacted subzone).
- Descriptions of these separations should also identify the kind of subzone described.
- Very thin surface crusts (less than about 1 cm thick) are generally described as a special surface feature rather than as a separate layer.

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Kinds of Near Surface Subzones

- In this section, five kinds of near surface subzones are presented and the general processes leading to their formation are described.
- The five kinds of subzones are: mechanically bulked, mechanically compacted, water compacted, surficial bulked, and crust (either biological or chemical).
- The figure here shows stylized profiles depicting various combinations of these subzones.

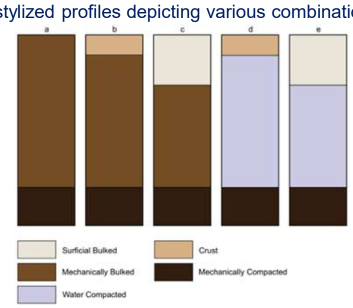

Figure 5: Five kinds of near surface subzones (scale is approximately 18 cm).

(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- Identification of subzones is not clear cut.
- Morphological expression of bulking and compaction may be quite different among soils depending on particle-size distribution, organic matter content, clay mineralogy, water regime, or other factors.
- The distinction between a bulked and compacted state for soil material with appreciable shrink-swell potential is partly based on the potential for the transmission of strain on drying over distances greater than the horizontal dimensions of the larger structural units.
- In a bulked subzone, little or no strain is propagated; in a compacted subzone, the strain is propagated over distances greater than the horizontal dimensions of the larger structural units.
- Many soils have low shrink-swell potential because of texture, clay mineralogy, or both.
- For these soils, the expression of cracks cannot be used to distinguish between a bulked state and a compacted state.

- The distinction between compaction and bulking is subjective.
- It is useful to establish a concept of a normal degree of compaction of the near surface and then compare the actual degree of compaction to this.
- The concept for tilled soils should be the compaction of soil material on level or convex parts of the tillage-determined relief.
- The soil should have been subject to the bulking action of conventional tillage without the subsequent mechanical compaction.
- The subzone in question should have been brought to a wet or very moist water state from an appreciably drier condition and then dried to slightly moist or drier at least once.
- It should not have been subject, however, to a large number of wetting and drying cycles where the maximum wetness involved the presence of free water.
- If the soil material has a degree of compaction similar to what would be expected, then the term normal compaction is used.

Mechanically Bulked Subzone

- The mechanically bulked subzone has undergone, through mechanical manipulation, a reduction in bulk density and an increase in discreteness of structural units, if present.
- The mechanical manipulation is commonly due to tillage operations.
- Rupture resistance of the mass overall, inclusive of a number of structural units, is typically loose or very friable and is occasionally friable.
- Individual structural units may be friable or even firm.

- Mechanical continuity among structural units is low.
- Structure grade, if the soil material exhibits structural units less than 20 mm across, is moderate or strong.
- Strain that results from contraction on drying of individual structural units may not extend across the structural units.
- Hence, internally initiated desiccation cracks may be weak or absent even though the soil material in a consolidated condition has considerable shrink-swell potential.
- Cracks may be present, however, if they initiate deeper in the soil.
- The mechanically bulked subzone is depicted in figure 5 as the first layer in profile a and the second layer in profiles b and c.

Mechanically Compacted Subzone

- The mechanically compacted subzone has been subject to compaction, usually due to tillage operations but also by animals.
- Commonly, mechanical continuity of the fabric and bulk density are increased.
- Rupture resistance depends on texture and degree of compaction.
- Generally, friable is the minimum class.
- Mechanical continuity of the fabric permits propagation of strain (that results on drying) only over several centimeters.
- Internally initiated cracks appear if the soil material has appreciable shrink-swell potential and drying was sufficient.
- In some soils this subzone restricts root growth.
- The suffix d may be used if compaction results in a strong plow pan.
- The mechanically compacted subzone is the lowest layer of all profiles shown in figure 5.

Water-Compacted Subzone

- The water-compacted subzone has been compacted by repetitive large changes in water state without mechanical load, except for the weight of the soil.
- Repetitive occurrence of free water is particularly conducive to compaction.
- Depending on texture, moist rupture resistance ranges from very friable through firm.
- Structural units, if present, are less discrete than those in the same soil material if mechanically bulked.
- The subzone generally has weak structure or is massive.

- Mechanical continuity of the fabric is sufficient for strain that originates on drying to propagate appreciable distances.
- As a consequence, if shrink-swell potential is sufficient, cracks develop on drying.
- In many soils, the water-compacted subzone replaces the mechanically bulked subzone over time.
- The replacement can occur in a single year if the subzone is subject to periodic occurrence of free water with intervening periods of being slightly moist or dry.
- The presence of a water-compacted subzone and the absence of a mechanically bulked subzone is an important consequence of no-till farming systems.
- The water-compacted subzone is depicted in figure 5 as the second layer of profiles d and e.

Surficial Bulked Subzone

- The surficial bulked subzone occurs in the very near surface.
- Continuity of the fabric is low.
- Cracks are not initiated in this subzone but may be present (they may initiate in underlying, more compacted soil).
- The subzone forms by various processes.
- Frost action under conditions where the soil is drier than wet is one process.
- Pronounced shrinking and swelling in response to drying and wetting (which is characteristic of Vertisols) is another process.
- The surficial bulked subzone is depicted in figure 5 as the first layer of profiles c and e.

Crust

- A crust is a surficial subzone, typically less than 50 mm thick but ranging to as much as 100 mm thick, that exhibits markedly more mechanical continuity of the soil fabric than the zone immediately beneath.
- Commonly, the original soil fabric has been reconstituted by water action and the original structure has been replaced by a massive condition.
- While the material is wet, raindrop impact (including sprinkler irrigation) and freeze-thaw cycles can lead to reconstitution.
- The crust is depicted in figure 5 as the first layer of profiles b and d.

- Crusts may be described in terms of thickness in millimeters, structure and other aspects of the fabric, and consistence, including rupture resistance while dry and micropenetration resistance while wet.
- Thickness pertains to the zone where reconstitution of the fabric has been pronounced.
- The distance between surface-initiated cracks (described later in this chapter) may be a useful observation for seedling emergence considerations.
- If the distance is short, the weight of the crust slabs is low.

- Soil material with little apparent reconstitution commonly adheres beneath the crust and is removed with the crust.
- This soil material, which shows little or no reconstitution, is not part of the crust and does not contribute to the thickness.
- Recognized types of soil crusts include biological, chemical and structural.

- Biological crusts, which consist of algae, lichens, or mosses, occur on the surface of some soils, especially in some relatively undisturbed settings, such as rangelands.
  - These crusts are easily diminished or destroyed by disturbance.
- Chemical crusts commonly occur in arid environments where salty evaporites accumulate at the surface.
  - They include crusts consisting of mineral grains cemented by salts.
- Structural crusts form from local transport and deposition of soil material, commonly in tilled fields.
  - They have weaker mechanical continuity than other crusts.
  - The rupture resistance is lower, and the reduction in infiltration may be less than that of crusts with similar texture.
  - Raindrop impact and freeze-thaw cycles contribute to the formation of structural crusts.

Root-Restricting Depth

- The root-restricting depth is the depth at which physical (including soil temperature) and/or chemical characteristics strongly inhibit root penetration.
- Restriction means the incapability to support more than a few fine or very fine roots if the depth from the soil surface and the water state (other than the occurrence of frozen water) are not limiting.
- For cotton, soybeans, and other crops that have less abundant roots than grasses have, the very few class is used instead of the few class.
- The restriction may be below where plant roots normally occur because of limitations in water state, temperatures, or depth from the surface.
- The root-restricting depth should be evaluated for the specific plants important to the use of the soil.
- These plants are indicated in the soil description.
- The root-restriction depth may differ depending on the plant.

Morphology and Root Restriction

- Root-depth observations should be used to make the generalization of root-restricting depth.
- If these are not available (commonly because roots do not extend to the depth of concern) then inferences may be made from morphology.
- A change in particle-size distribution alone (e.g., loamy sand over gravel) is not typically a basis for physical root restriction.
- Some guidelines for inferring physical restriction are given below.
- Chemical restrictions, such as high levels of extractable aluminum and/or low levels of extractable calcium, are not considered; these are generally not determinable by field examination alone.

- Physical root restriction is assumed:
  - 1. At the contact with bedrock and other continuously cemented materials, regardless of the rupture resistance class or thickness;
  - 2. For certain horizons or layers, such as fragipans or those consisting of densic materials, that, although non-cemented, are root restrictive by definition; and
  - 3. For layers with a combination of structure, consistence, and/or penetration resistance that suggests that the resistance of the soil fabric to root entry is high and that vertical cracks and planes of weakness for root entry are absent or widely spaced (i.e., more than 10 cm apart) as follows:
    - a. For a zone more than 10 cm thick that when very moist or wet is very firm (firm, if sandy) or firmer or that has a penetration resistance class of large (i.e., high or higher), and is massive or platy or has weak structure of any type.
    - b. For a zone that has structural units of any grade with a vertical repeat distance of more than 10 cm and while very moist or wet is very firm (firm, if sandy) or extremely firm, or has a large (i.e., high or higher) penetration resistance.

Classes of Root-Restricting Depth

- Terms describing depth to physical restriction for roots are:
  - Very shallow less than 25 cm
  - Shallow 25 to less than 50 cm
  - Moderately deep 50 to less than 100 cm
  - Deep 100 to less than 150 cm
  - Very deep 150 cm or more

Particle-Size Distribution

- This section discusses particle-size distribution of mineral soil separates.
- Fine earth indicates particles smaller than 2 mm in diameter.
- Fragments 2 mm or larger consist of rock fragments, pieces of geologic or pedogenic material with a strongly cemented or more cemented rupture-resistance class; pararock fragments, pieces of geologic or pedogenic material with an extremely weakly cemented to moderately cemented rupture-resistance class; and discrete artifacts, pieces of human-manufactured material.
- Particle-size distribution of fine earth is determined in the field mainly by feel.
- The content of rock fragments, pararock fragments, and discrete artifacts is an estimate of the proportion of the soil volume that they occupy.

Soil Separates

- After pretreatment to remove organic matter, carbonates, soluble salts, and other cementing agents and after dispersion to physically separate individual soil particles, the U.S. Department of Agriculture uses the following size separates for fine-earth fraction:
  - Very coarse sand < 2.0 to > 1.0 mm
  - Coarse sand 1.0 to > 0.5 mm
  - Medium sand 0.5 to > 0.25 mm
  - Fine sand 0.25 to > 0.10 mm
  - Very fine sand 0.10 to > 0.05 mm
  - Coarse silt 0.05 to > 0.02 mm
  - Fine silt 0.02 to > 0.002 mm
  - Coarse clay 0.002 to > 0.0002 mm
  - Fine clay less than or equal to 0.0002 mm

- The figure here compares the USDA system for naming various sizes of soil separates with four other systems: International; Unified; AASHTO; and Modified Wentworth.

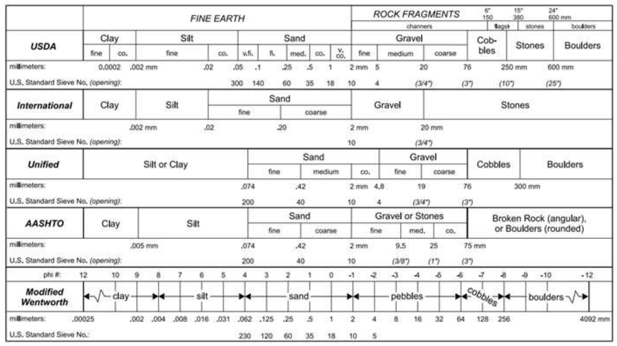

Figure 6: Relationships among particle-size classes of the USDA system and four other systems.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

Soil Texture

- Soil texture refers to the weight proportion of the separates for particles less than 2 mm in diameter as determined from a laboratory particle-size distribution.
- The pipette method is the preferred standard, but the hydrometer method also is used in field labs.
- If used, the hydrometer method should be noted with the results.

- Field estimates of soil texture class are based on qualitative criteria, such as how the soil feels (gritty, smooth, sticky) and how it responds to rubbing between the fingers to form a ribbon.
- Estimated field texture class should be checked against laboratory determinations, and the field criteria used to estimate texture class should be adjusted as necessary to reflect local conditions.
- Sand particles feel gritty and can be seen individually with the naked eye.
- Silt particles have a smooth feel to the fingers when dry or wet and cannot be seen individually without magnification.
- Clay soils are sticky in some areas and not sticky in others.
- For example, soils dominated by smectitic clays feel different from soils that contain similar amounts of micaceous or kaolinitic clay.
- The relationships that are useful for judging texture of one kind of soil may not apply as well to another kind.

- Some soils are not dispersed completely in the standard laboratory particle-size analysis.
- Examples include soils with andic soil properties (high amounts of poorly crystalline, amorphous minerals) and soils with high contents of gypsum (more than about 25 percent).
- For soils like these, for which the estimated field texture class and the laboratory measured particle-size distribution differ markedly, the field texture is referred to as apparent because it is not an estimate that correlates well with the results of a laboratory test.
- Apparent field texture is only a tactile evaluation and does not infer laboratory test results.
- The twelve texture classes are sands, loamy sands, sandy loams, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay.
- Subclasses of sand are coarse sand, sand, fine sand, and very fine sand.
- Subclasses of loamy sands and sandy loams that are based on sand size are named similarly.

Definitions of Soil Texture Classes and Subclasses

- Sands: Material has more than 85 percent sand, and the percentage of silt plus 1.5 times the percentage of clay is less than 15.
  - Coarse sand: Material has a total of 25 percent or more very coarse and coarse sand and less than 50 percent any other single grade of sand.
  - Sand: Material has a total of 25 percent or more very coarse, coarse, and medium sand, a total of less than 25 percent very coarse and coarse sand, and less than 50 percent fine sand and less than 50 percent very fine sand; OR material has 25 percent or more very coarse and coarse sand and 50 percent or more medium sand.
  - Fine sand: Material has 50 percent or more fine sand, and fine sand exceeds very fine sand; OR material has a total of less than 25 percent very coarse, coarse, and medium sand and less than 50 percent very fine sand.
  - Very fine sand: Material has 50 percent or more very fine sand.

- Loamy sands: Material has between 70 and 90 percent sand, the percentage of silt plus 1.5 times the percentage of clay is 15 or more, and the percentage of silt plus twice the percentage of clay is less than 30.
  - Loamy coarse sand: Material has a total of 25 percent or more very coarse and coarse sand and less than 50 percent any other single grade of sand.
  - Loamy sand: Material has a total of 25 percent or more very coarse, coarse, and medium sand, a total of less than 25 percent very coarse and coarse sand, and less than 50 percent fine sand and less than 50 percent very fine sand; OR material has a total of 25 percent or more very coarse and coarse sand and 50 percent or more medium sand.
  - Loamy fine sand: Material has 50 percent or more fine sand or less than 50 percent very fine sand and a total of less than 25 percent very coarse, coarse, and medium sand.
  - Loamy very fine sand: Material has 50 percent or more very fine sand.

- Sandy loams: Material has 7 to less than 20 percent clay and more than 52 percent sand, and the percentage of silt plus twice the percentage of clay is 30 or more; OR material has less than 7 percent clay and less than 50 percent silt, and the percentage of silt plus twice the percentage of clay is 30 or more.
  - Coarse sandy loam: Material has a total of 25 percent or more very coarse and coarse sand and less than 50 percent any other single grade of sand; OR material has a total of 30 percent or more very coarse, coarse, and medium sand, and very fine sand is 30 to less than 50 percent.
  - Sandy loam: Material has a total of 30 percent or more very coarse, coarse, and medium sand but a total of less than 25 percent very coarse and coarse sand, less than 30 percent fine sand, and less than 30 percent very fine sand; OR material has a total of 15 percent or less very coarse, coarse, and medium sand, less than 30 percent fine sand, and less than 30 percent very fine sand with a total of 40 percent or less fine and very fine sand; OR material has a total of 25 percent or more very coarse and coarse sand and 50 percent or more medium sand.

  - Fine sandy loam: Material has 30 percent or more fine sand, less than 30 percent very fine sand, and a total of less than 25 percent very coarse and coarse sand; OR material has a total of 15 to less than 30 percent very coarse, coarse, and medium sand and a total of less than 25 percent very coarse and coarse sand; OR material has a total of 40 percent or more fine and very fine sand (and fine sand equals or exceeds very fine sand) and a total of 15 percent or less very coarse, coarse, and medium sand; OR material has a total of 25 percent or more very coarse and coarse sand and 50 percent or more fine sand.
  - Very fine sandy loam: Material has 30 percent or more very fine sand and a total of less than 15 percent very coarse, coarse, and medium sand, and very fine sand exceeds fine sand; OR material has 40 percent or more fine and very fine sand (and very fine sand exceeds fine sand) and a total of less than 15 percent very coarse, coarse, and medium sand; OR material has 50 percent or more very fine sand and a total of 25 percent or more very coarse and coarse sand; OR material has a total of 30 percent or more very coarse, coarse, and medium sand and 50 percent or more very fine sand.

- Loam: Material has 7 to less than 27 percent clay, 28 to less than 50 percent silt, and 52 percent or less sand.
- Silt loam: Material has 50 percent or more silt and 12 to less than 27 percent clay; OR material has 50 to less than 80 percent silt and less than 12 percent clay.
- Silt: Material has 80 percent or more silt and less than 12 percent clay.
- Sandy clay loam: Material has 20 to less than 35 percent clay, less than 28 percent silt, and more than 45 percent sand.

- Clay loam: Material has 27 to less than 40 percent clay and more than 20 to 45 percent sand.
- Silty clay loam: Material has 27 to less than 40 percent clay and 20 percent or less sand.
- Sandy clay: Material has 35 percent or more clay and more than 45 percent sand.
- Silty clay: Material has 40 percent or more clay and 40 percent or more silt.
- Clay: Material has 40 percent or more clay, 45 percent or less sand, and less than 40 percent silt.

- The USDA textural triangle is shown in the figure here.

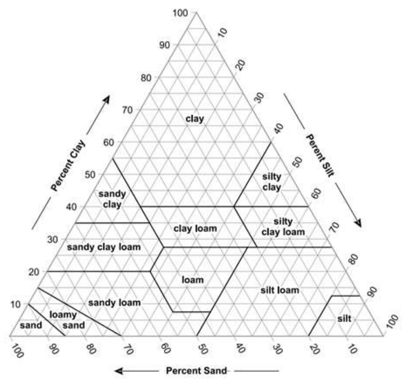

Figure 7: USDA textural triangle showing the percentages of clay, silt, and sand in the 12 basic texture classes.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- A soil sample is assigned to one of the twelve soil texture classes according to the values for the proportions of sand, silt, and clay, which are located along each of the three axes.
- The eight subclasses in the sand and loamy sand groups provide refinement that in some cases may be greater than can be consistently determined by field techniques.
- Only those distinctions that are significant to use and management and that can be consistently made in the field should be applied when determinations of texture are based on field estimates alone.

Groupings of Soil Texture Classes

- The need for fine distinctions in the texture of the soil layers results in a large number of classes and subclasses of soil texture.
- It commonly is convenient to speak generally of broad groups or classes of texture.
- The table here provides an outline of three general soil texture groups and five subgroups.
- In some areas where soils have a high content of silt, a fourth general class, silty soil materials, may be used for silt and silt loam.

General texture groups and subgroups*	Texture classes
Sandy soil materials	
Coarse textured	Sands (coarse sand, sand, fine sand, very fine sand); loamy sands (loamy coarse sand, loamy sand, loamy fine sand, loamy very fine sand)
Loamy soil materials	
Moderately coarse textured	Coarse sandy loam, sandy loam, fine sandy loam
Medium textured	Very fine sandy loam, loam, silt loam, silt
Moderately fine textured	Clay loam, sandy clay loam, silty clay loam
Clayey soil materials	
Fine textured	Sandy clay, silty clay, clay

* Note: These are not the sandy, loamy, and clayey family particle-size classes defined in *Soil Taxonomy*.

Table 1: General Soil Texture Groups.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

Terms Used in Lieu of Soil Texture

- There are some horizons or layers for which soil texture class terms are not applicable.
- These include bedrock and other cemented horizons (such as petrocalcic horizons, duripans, etc.), those composed of organic soil materials, and those composed of water, either liquid or frozen, below a mineral or organic soil surface layer.
- Other exceptions include layers composed of more than 90 percent rock fragments or artifacts and horizons or layers composed of 40 percent or more gypsum in the fine-earth fraction (and that are not cemented).
- These exceptions are discussed below.

Soil Materials with a High Content of Gypsum

- For soil materials with 40 percent or more, by weight, gypsum in the fine-earth fraction, gypsum dominates the physical and chemical properties of the soil to the extent that particle-size classes are not meaningful.
- Two terms in lieu of texture are used:
  - Coarse gypsum material: 50 percent or more of the fine-earth fraction is comprised of particles ranging from 0.1 to 2.0 mm in diameter.
  - Fine gypsum material: Less than 50 percent of the fine-earth fraction is comprised of particles ranging from 0.1 to 2.0 mm in diameter.

Bedrock and Cemented Horizons

- These horizons or layers are described as bedrock or cemented material.
- Additional information about the kind of rock, degree of cementation, and kind of cementing agent can also be provided.

Water Layers

- These layers are described as water or ice.
- They only refer to subsurface layers, such as in a floating bog.
- Figure 3 shows a subsoil layer of ice.

Soil Materials with a High Content of Rock or Pararock Fragments Horizons

- For soil materials with more than 90 percent rock or pararock fragments, there is not enough fine earth to determine the texture class.
- In these cases, the terms gravel, cobbles, stones, boulders, channers, and flagstones or their pararock fragment equivalents are used.

Soil Materials with a High Content of Artifacts

- For soil materials with more than 90 percent artifacts, the term artifacts is used.

Organic Soils

- Layers that are not saturated with water for more than a few days at a time are organic if they have 20 percent or more organic carbon.
- Layers that are saturated for longer periods, or were saturated before being drained, are organic if they have 12 percent or more organic carbon and no clay, 18 percent or more organic carbon, and 60 percent or more clay or have a proportional amount of organic carbon, between 12 and 18 percent, if the clay content is between 0 and 60 percent.
- The required organic carbon content for saturated soils having between 0 and 60 percent clay can be calculated as:
- $OC_{required}$ = 12+(0.1 * percent clay).
- Soils with more than 60 percent clay need an organic carbon content of at least 18 percent.

- The kind and amount of the mineral fraction, the kind of organisms from which the organic material was derived, and the state of decomposition affect the properties of the soil material.
- Descriptions include the percentage of undecomposed fibers and the solubility in sodium pyrophosphate of the humified material.
- Attention should be given to identifying and estimating the volume occupied by sphagnum fibers, which have extraordinary high water retention.
- When squeezed firmly in the hand to remove as much water as possible, sphagnum fibers are lighter in color than fibers of hypnum and most other mosses.

- Fragments of wood more than 20 mm across and so undecomposed that they cannot be crushed by the fingers when moist or wet are called wood fragments.
- They are comparable to rock fragments in mineral soils and are described in a comparable manner.
- Saturated organic soil materials: The types of organic soil materials that are described in saturated organic soil materials are:
    - Muck: Well decomposed organic soil material with a low content of fibers (plant tissue excluding live roots).
    - Peat: Slightly decomposed organic soil material with a high content of original fibers.
    - Mucky peat: Organic soil material that is intermediate in degree of decomposition, fiber content, bulk density, and water content between muck and peat.
- Muck, peat, and mucky peat may be described in both organic and mineral soils provided the soils are saturated with water for 30 or more cumulative days in normal years or are artificially drained.
- These materials only qualify for the diagnostic sapric, fibric, and hemic soil material of Soil Taxonomy when they occur in organic soils (i.e., the soil of the order Histosols and the suborder Histels).

- Non-saturated organic soil materials: The types of organic soil materials that are described in layers not saturated for 30 or more cumulative days are:
  - Highly decomposed plant material: Well decomposed, organic soil material with a low content of fibers (plant tissue excluding live roots).
  - Moderately decomposed plant material: Material intermediate in degree of decomposition, fiber content, bulk density, and water content between highly decomposed and slightly decomposed plant material.
  - Slightly decomposed plant material: Slightly decomposed organic soil material with a high content of original fibers.

Modifiers for Terms Used in Lieu of Texture

- Modifiers may be needed to better describe the soil material making up the horizon or layer.
- These include terms for significant amounts of particles 2.0 mm or larger (rock fragments, pararock fragments, or artifacts) and terms that indicate the composition of the soil material.

Soil Materials with Rock Fragments, Pararock Fragments, or Artifacts

- To describe soils with 15 percent or more, by volume, rock fragments, pararock fragments, or artifacts, the texture terms are modified with terms indicating the amount and kind of fragments.
- Examples include very gravelly loam, extremely paracobbly sand, and very artifactual sand.
- The conventions for use of these terms and the definitions of class terms are discussed in the following sections on rock fragments, pararock fragments, and artifacts.

Class Modifiers Indicating Soil Material Composition

- Soil composition modifiers are used for some soils that have andic properties or formed in volcanic materials, soils that have a high content of gypsum, some organic soil materials, and mineral soil materials with a high content of organic matter.
- Terms are also provided for limnic soil materials and permanently frozen layers (permafrost).

Soil Materials with Andic Properties or Volcanic Origin

- Hydrous: Material that has andic soil properties and an undried 15 bar (1500 kPa) water content of 100 percent or more of the dry weight (e.g., hydrous clay).
- Medial: Material that has andic soil properties and has a 15 bar (1500 kPa) water content of less than 100 percent on undried samples and of 12 percent or more on air-dried samples (e.g., medial silt loam).
- Ashy: Material that has andic soil properties and is neither hydrous nor medial, or material that does not have andic soil properties and the chemistry and physical makeup of its fine-earth fraction reflects the weathering processes of volcanic materials (e.g., ashy loam).
    - The weathering processes of volcanic materials are evidenced by 30 percent or more particles 0.02 to 2.0 mm in diameter, of which 5 percent or more is composed of volcanic glass and the [(aluminum plus ½ iron percent by ammonium oxalate) times 60] plus the volcanic glass percent is equal to or more than 30.

Soil Materials with Gypsum

- Gypsiferous: Material that contains 15 to less than 40 percent, by weight, gypsum (e.g., gypsiferous fine sandy loam).
- For material that has 40 percent or more gypsum, a term in lieu of texture is used (e.g., fine gypsum material or coarse gypsum material).

Organic Soil Materials

- Modifiers are only used with the "in lieu of texture" terms muck, peat, or mucky peat.
- The following modifiers are used only for organic soil materials that are saturated with water for 30 or more cumulative days in normal years or are artificially drained.
- Woody: Material contains 15 percent or more wood fragments larger than 20 mm in size or contains 15 percent or more fibers that can be identified as wood origin and has more wood fibers than any other kind of fiber (e.g., woody muck).
- Grassy: Material contains more than 15 percent fibers that can be identified as grass, sedges, cattails, and other grasslike plants and contains more grassy fibers than any other kind of fiber (e.g., grassy mucky peat).
- Mossy: Material contains more than 15 percent fibers that can be identified as moss and contains more moss fibers than any other kind of fiber (e.g., mossy peat).
- Herbaceous: Material contains more than 15 percent fibers that can be identified as herbaceous plants other than moss and grass or grasslike plants and has more of these fibers than any other kind of fiber (e.g., herbaceous muck).

Mineral Soil Materials with a High Content of Organic Matter

- Highly organic: Term indicates near surface horizons of mineral soils that are saturated with water for less than 30 cumulative days in normal years and are not artificially drained (e.g., highly organic loam).
  - Excluding live roots, the horizon has organic carbon content (by weight) of one of the following:
    - 5 to < 20 percent if the mineral fraction contains no clay,
    - 12 to < 20 percent if the mineral fraction contains 60 percent or more clay, or
    - [5 + (clay percentage multiplied by 0.12)] to < 20 percent if the mineral fraction contains less than 60 percent clay.

- Mucky: Term indicates near surface horizons of mineral soils that are saturated with water for 30 or more cumulative days in normal years or are artificially drained (e.g., mucky silt loam).
  - Excluding live roots, the horizon has more than 10 percent organic matter and less than 17 percent fibers.
- Peaty: Term indicates near surface horizons of mineral soils that are saturated with water for 30 or more cumulative days in normal years or are artificially drained (e.g., peaty clay loam).
  - Excluding live roots, the horizon has more than 10 percent organic matter and 17 percent or more fibers.

Limnic Soil Materials

- Limnic soil materials occur in layers underlying some soils of the soil order Histosols.
- By definition they are not recognized in mineral soils.
- They are mineral or organic soil materials originating from aquatic organisms or from aquatic plants that were later altered by aquatic organisms.

- The following terms are used to describe the origin of the limnic materials:
  - Coprogenous: Material contains many very small (0.1 to 0.001 mm) fecal pellets (e.g., coprogenous sandy loam).
  - Diatomaceous: Material is composed dominantly of diatoms (e.g., diatomaceous silt loam).
  - Marly: Material is composed dominantly of calcium carbonate “mud” (e.g., marly silty clay).
- Layers for which these terms are used may or may not also meet the definition for coprogenous earth, diatomaceous earth, or marl as defined in Soil Taxonomy.

Permafrost

- Layers of permafrost are described as permanently frozen (e.g., permanently frozen loamy sand).

Rock Fragments and Pararock Fragments

- Rock fragments are unattached pieces of geologic or pedogenic material 2 mm in diameter or larger that have a strongly cemented or more cemented rupture-resistance class.
- Pararock fragments are unattached pieces of geologic or pedogenic material 2 mm in diameter or larger that are extremely weakly cemented through moderately cemented.
- Pararock fragments are not retained on sieves because they are crushed by grinding during the preparation of samples for particle-size analysis in the laboratory.

- Rock fragments and pararock fragments include all sizes between 2.0 mm and horizontal dimensions smaller than the size of a pedon.
- The words "rock" and "pararock" are used here in the broad sense and connote more than just natural fragments of geologic material.
- Thus, rock and pararock fragments may be discrete, cemented pieces of bedrock, bedrock-like material, durinodes, concretions, nodules, or pedogenic horizons (e.g., petrocalcic fragments).
- Artifacts, however, are not included as rock or pararock fragments. They are described separately.

- Rock fragments and pararock fragments are described by size, shape, hardness, roundness, and kind of fragment.
- The classes are gravel, cobbles, channers, flagstones, stones, and boulders and their pararock counterparts (i.e., paragravel, paracobbles, etc.).
- If a size or range of sizes predominates, the class is modified (e.g., "fine gravel," "cobbles 100 to 150 mm in diameter," "channers 25 to 50 mm in length").

- Gravel and paragravel are a collection of fragments that have diameters ranging from 2 to 76 mm.
- Individual fragments in this size range are properly referred to as "pebbles," not "gravels."
- The term gravel as used here indicates the collection of pebbles in a soil horizon and does not imply a geological formation.

- The terms "pebble" and "cobble" are typically restricted to rounded or subrounded fragments; however, they can be used to describe angular fragments that are not flat.
- Words such as "chert," "limestone," and "shale" refer to a kind or lithology of rock, not a piece of rock.
- The composition of the fragments can be given, for example: "chert gravel," "limestone channers," "siltstone parachanners."

- The upper size limit of gravel and paragravel is 76 mm (3 inches).
- This coincides with the upper limit used by many engineers for grainsize distribution computations.
- The 5-mm and 20-mm divisions for the separation of fine, medium, and coarse gravel coincide with the sizes of openings in the number 4 screen (4.76-mm) and the ¾-inch (19.05-mm) screen used in engineering.

- The 76-mm (3-inch) limit separates gravel from cobbles, the 250-mm (10-inch) limit separates cobbles from stones, and the 600-mm (24-inch) limit separates stones from boulders.
- The 150-mm (6-inch) and 380-mm (15-inch) limits for thin, flat channers and flagstones, respectively, follow conventions used for many years to provide class limits for plate-shaped and crudely spherical rock fragments that have about the same soil use implications as the 250-mm limit for spherical shapes.

Estimating Rock Fragments in the Soil

- Rock fragments in the soil can greatly influence use and management.
- It is important to not only consider the total amount of rock fragments, but also the proportions of the various size classes (gravel, cobbles, stones, etc.).
- A soil with 10 percent stones is quite different from one with 10 percent gravel.
- When developing interpretive criteria, a distinction must be made between volume and weight percent of rock fragments.
- Field descriptions generally record estimates of volume, while laboratory measurements of rock fragments are given as weight for the various size classes.

- The National Cooperative Soil Survey in the United States uses interpretive algorithms based on weight percent of the > 250, > 76-250, > 5-76, and 2-5 mm fractions when rating soils for various potential uses.
- The first two size ranges are on a whole soil basis, and the latter two are on a < 76 mm basis.
- For the > 250 and > 76-250 mm fractions, weighing is generally impracticable and volume percentage estimates are made from areal percentage measurements by point-count or line-intersect methods.
- Length of the transect or area of the exposure should be at least 50 times, and preferably 100 times, the area or dimensions of the rock fragment size that encompasses about 90 percent of the rock fragment volume.

- For the < 76 mm weight, measurements are feasible but may require 50 to 60 kg of sample if appreciable rock fragments near 76 mm are present.
- An alternative is to obtain volume estimates for the 20-76 mm fraction and weight estimates for the < 20 mm fraction.
- This method is preferred because of the difficulty in visual evaluation of the 2 to 5 mm size separations.
- The weight percentages of > 5-20 mm and 2-5 mm fractions may be converted to volume estimates and placed on a < 76 mm base by computation.

Terms for Rock Fragments and Their Use in Modifying Texture Classes

- The adjectival form of a class name of rock fragments or pararock fragments is used as a modifier of the texture class name, e.g., paragravelly loam, very cobbly sandy loam.
- Table 3 provides rules for determining the proper texture modifier term for material with a mixture of rock fragment sizes.
- This section also provides rules for assigning terms for soils with a mixture of rock and pararock fragments.

Shape and size	Noun*	Adjective*
Nonflat fragments (spherical or cubelike):		
2–76 mm diameter	Gravel	Gravelly
2–5 mm diameter	Fine gravel	Fine gravelly
> 5–20 mm diameter	Medium gravel	Medium gravelly
> 20–76 mm diameter	Coarse gravel	Coarse gravelly
> 76–250 mm diameter	Cobbles	Cobbly
> 250–600 mm diameter	Stones	Stony
> 600 mm diameter	Boulders	Bouldery
Flat fragments:		
2–150 mm long	Channers	Channery
> 150–380 mm long	Flagstones	Flaggy
> 380–600 mm long	Stones	Stony
> 600 mm long	Boulders	Bouldery

* For fragments that are less than strongly cemented, the prefix "para" is added to the terms in this table to form either a descriptive noun or the adjective for the texture modifier (e.g., paracobbles, paragravelly).

Table 2: Terms for Rock Fragments and Pararock Fragments.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- The following classes, based on volume percentages, are used:
  - Less than 15 percent: No texture modifier terms are used with soils having less than 15 percent gravel, paragravel, cobbles, paracobbles, channers, parachanners, flagstones, or paraflagstones.
  - 15 to less than 35 percent: The adjectival term of the dominant kind of fragment is used as a modifier of the texture class, e.g., gravelly loam, parachannery silt loam, cobbly sandy loam.
  - 35 to less than 60 percent: The adjectival term of the dominant kind of rock fragment is used with the word "very" as a modifier of the texture class, e.g., very gravelly loam, very parachannery silt loam, very cobbly loamy sand.
  - 60 to less than 90 percent: The adjectival term of the dominant kind of rock fragment is used with the word "extremely" as a modifier of the texture class, e.g., extremely gravelly loam, extremely parachannery silt loam, extremely cobbly sandy loam.
  - 90 percent or more: No texture modifier terms are used. If there is too little fine earth to determine the texture class (less than about 10 percent, by volume) a term in lieu of texture (i.e., gravel, cobbles, stones, boulders, channers, flagstones, or their pararock fragment equivalents) is used as appropriate.

Figure 8: A soil in which the layers below a depth of about 20 cm are very cobbly loamy sand. Left side of scale is in 20-cm increments.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- The class limits apply to the volume of the layer occupied by all rock fragments 2 mm in diameter or larger.
- The soil generally contains fragments smaller or larger than those identified by the term.
- For example, very cobbly sandy loam typically contains gravel but "gravelly" is not in the name.
- The use of a term for larger pieces of rock, such as boulders, does not imply that the pieces are entirely within a given soil layer.
- A single boulder may extend through several layers.

- Table 3 can be used to determine the proper modifier if there is a mixture of rock fragment sizes.
- To use the table, first choose the row with the appropriate total rock fragments.
- Then read the criteria in the columns under "Gravel, cobbles, stones, and boulders," starting from the left-most column and proceeding to the right. Stop in the first column in which a criterion is met.

Total rock fragments *(Vol. %)*	Gravel (GR), cobbles (CB), stones (ST), and boulders (BY) (Substitute channers for gravel and flagstones for cobbles, where applicable)			
	If GR ≥ 1.5 CB + 2 ST + 2.5 BY	If CB ≥ 1.5 ST + 2 BY	If ST ≥ 1.5 BY	If ST < 1.5 BY
≥ 15 < 35	Gravelly	Cobbly	Stony	Bouldery
≥ 35 < 60	Very gravelly	Very cobbly	Very stony	Very bouldery
≥ 60 < 90	Extremely gravelly	Extremely cobbly	Extremely stony	Extremely bouldery
≥ 90	Gravel	Cobbles	Stones	Boulders

Table 3: Guide for Determining Rock Fragment Modifier of Texture for Soils with a Mixture of Rock Fragment Sizes.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- More precise estimates of the amounts of rock fragments than are provided by the defined classes are needed for some purposes.
- For more precise information, estimates of percentages of each size class or a combination of size classes are included in the description, e.g., "very cobbly sandy loam," "30 percent cobbles and 15 percent gravel or silt loam," "about 10 percent gravel."
- If loose pieces of rock are significant to the use and management of a soil, they are the basis of phase distinctions among map units.
- Exposed bedrock is not soil and is identified separately in mapping as a kind of miscellaneous area (i.e., Rock outcrop).

- The volume occupied by individual pieces of rock can be seen, and their aggregate volume percentage can be calculated.
- For some purposes, volume percentage must be converted to weight percentage.
- The following rules are used to select texture modifiers if a horizon includes both rock and pararock fragments:
  - 1. Describe the individual kinds and amounts of rock and pararock fragments.
  - 2. Do not use a fragment texture modifier if the combined volume of rock and pararock fragments is less than 15 percent.
  - 3. If the combined volume of rock and pararock fragments is more than 15 percent and the volume of rock fragments is less than 15 percent, assign pararock fragment modifiers based on the combined volume of fragments.
    - For example, use “paragravelly” as a texture modifier forsoils with 10 percent rock and 10 percent pararock gravel-sized fragments.
  - 4. If the volume of rock fragments is 15 percent or more, use the appropriate texture modifier for rock fragments regardless of the volume of pararock fragments.

Rock Fragment Hardness, Roundness, and Kind

- Fragment hardness is equivalent to the rupture resistance class for a cemented fragment of specified size that has been air dried and then submerged in water.
- The hardness of a fragment is significant where the rupture resistance class is strongly cemented or greater.
- Fragment roundness is an expression of the sharpness of the edges and corners of rock fragments and pararock fragments.
- The roundness of fragments impacts water infiltration, root penetration, and macropore space.

- The following roundness classes are used:
  - Very angular Strongly developed faces and very sharp, broken edges
  - Angular Strongly developed faces and sharp edges
  - Subangular Detectable flat faces and slightly rounded corners
  - Subrounded Detectable flat faces and well rounded corners
  - Rounded Flat faces absent or nearly absent and all corners rounded
  - Well rounded Flat faces absent and all corners rounded

- Fragment kind is the lithology or composition of the 2 mm or larger fraction of the soil.
- Kinds of fragments are varied based on whether their origin is from a geologic source or a pedogenic source.
- Examples of kinds of fragments are basalt fragments, durinodes, iron-manganese concretions, limestone fragments, petrocalcic fragments, tuff fragments, and wood fragments.

Artifacts

- Artifacts are discrete water-stable objects or materials created, modified, or transported from their source by humans, usually for a practical purpose in habitation, manufacturing, excavation, agriculture, or construction activities.
- Examples are processed wood products, coal combustion by-products, bitumen (asphalt), fibers and fabrics, bricks, cinder blocks, concrete, plastic, glass, rubber, paper, cardboard, iron and steel, altered metals and minerals, sanitary and medical waste, garbage, and landfill waste.
- Artifacts also include natural materials which were mechanically abraded by human activities (as evidenced by scrapes, gouges, tool marks, etc.), such as shaped or carved stone work, grindstones, and shaped stones and debitage (e.g., stone tool flakes).

- Artifacts are generally categorized as either particulate or discrete.
- The distinction is based on size: particulate artifacts have a diameter of less than 2 mm and discrete artifacts have a diameter of 2 mm or more.
- Discrete artifacts are easier to identify and are essentially fragments of human origin.
- Particulate artifacts are sometimes difficult to discern from naturally occurring fine-earth soil material.

Describing Artifacts in Soil

- Artifacts are described if they are judged to be durable enough to persist in the soil (resist weathering and leaching) for a few decades or more.
- Descriptions of artifacts generally include quantity, cohesion, persistence, size, and safety classes.
- They may also include shape, kind, penetrability by roots, and roundness.
- Additional attributes (such as those discussed below under the heading "Consistence") may be described to help understand and interpret the soil.
- The conventions for describing artifacts are explained in the following paragraphs.

- Quantity refers to the estimated volume percent of a horizon or other specified unit occupied by discrete artifacts.
    - If classes (rather than quantitative estimates) are given, they are the same as those described in this chapter for mottles.
- Cohesion refers to the relative ability of the artifact to remain intact after significant disturbance.
    - The cohesion classes are:
        - Cohesive: Artifacts adhere together sufficiently so that they cannot be easily broken into pieces < 2 mm either by hand or with a simple crushing device, such as a mortar and pestle.
        - Noncohesive: Artifacts are easily broken into pieces < 2 mm either by hand or with a simple crushing device, such as a mortar and pestle.
            - Noncohesive artifacts are similar to pararock fragments and will be incorporated into the fine-earth fraction of the soil during routine laboratory sample preparation.

- Penetrability describes the relative ease with which roots can penetrate the artifact and potentially extract any stored moisture, nutrients, or toxic elements.
  - The penetrability classes are:
    - Nonpenetrable: Roots cannot penetrate through the solid parts of the artifact or between the component parts of the artifact.
    - Penetrable: Roots can penetrate through the solid parts of the artifact or between the component parts of the artifact.

- Persistence describes the relative ability of solid artifacts to withstand weathering and decay over time.
  - Local conditions, such as temperature and moisture, significantly impact the persistence of artifacts in the soil.
  - The persistence classes are:
    - Nonpersistent: The artifact is susceptible to relatively rapid weathering or decay and is expected to be lost from the soil in less than a decade.
      - Loss of soil mass and eventually subsidence result.
    - Persistent: The artifact is expected to remain intact in the soil for a decade or more.

- Roundness indicates the sharpness of edges and corners of natural objects, such as rock fragments, and human-manufactured objects, such as artifacts.
  - The artifact roundness classes are the same as those used for fragment roundness.
- Safety describes the degree of risk to humans from contact with soils that contain artifacts.
  - Physical contact with soils containing dangerous or harmful artifacts should be avoided unless proper training is provided and protective clothing is available.
  - The safety classes are:
    - Innocuous: The artifacts are considered to be harmless to living beings.
      - Examples include untreated wood products, iron, bricks, cinder blocks, concrete, plastic, glass, rubber, organic fibers, inorganic fibers, unprinted paper and cardboard, and some mineral and metal products.
      - Sharp innocuous artifacts can cause injury, but the materials themselves are still considered innocuous.
    - Noxious: The artifacts are potentially harmful or destructive to living beings unless dealt with carefully.
      - The harm may be immediate or long-term and through direct or indirect contact.
      - Examples include arsenic-treated wood products, batteries, waste and garbage, radioactive fallout, liquid petroleum products, asphalt, coal ash, paper printed with metallic ink, and some mineral and metal products.

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- Shape is variable among kinds of artifacts.
  - The shape classes are:
    - Elongated: One dimension is at least three times longer than both of the others.
    - Equidimensional: Dimensions in length, width, and height are approximately similar.
    - Flat: One dimension is less than one third that of both of the others, and one dimension is less than three times that of the intermediate dimension.
    - Irregular: The form is branching and convoluted.

- Size may be measured and reported directly or given as a class.
  - The dimension to which size-class limits apply depends on the shape of the artifact described.
  - If the shape is nearly uniform, size is measured in the shortest dimension, such as the effective diameter of a cylinder or the thickness of a plate.
  - For elongated or irregular bodies, size generally refers to the longest dimension but direct measurements for 2 or 3 dimensions can be given for clarification. The size classes for discrete artifacts are:
    - Fine 2 to < 20 mm
    - Medium 20 to < 75 mm
    - Coarse 75 to < 250 mm
    - Very coarse ≥ 250 mm

Kinds of Artifacts

- There are too many varieties of artifacts to provide a comprehensive list.

- The most common types include:
  - Noxious and innocuous artifacts
  - Treated and untreated wood products
  - Liquid petroleum products
  - Coal combustion by-products
  - Paper (printed and unprinted) and cardboard
  - Sanitary and medical waste
  - Garbage and landfill waste
  - Organic and inorganic fibers
  - Asphalt
  - Bricks
  - Cinder blocks
  - Concrete
  - Plastic
  - Glass
  - Rubber products
  - Iron and steel

Texture Modifier Terms for Soils with Artifacts

- The texture of soils with artifacts is described according to the content of artifacts:
    - Less than 15 percent: No texture modifier terms are used.
    - 15 to less than 35 percent: The term "artifactual" is used, e.g., artifactual loam.
    - 35 to less than 60 percent: The term "very artifactual" is used, e.g., very artifactual loam.
    - 60 to less than 90 percent: The term "extremely artifactual" is used, e.g., extremely artifactual loam.
    - 90 percent or more: No texture modifier terms are used.
        - If there is not enough fine earth to determine the texture class (less than about 10 percent, by volume) the term "artifacts" is used.

Compound Texture Modifiers

- In some cases, the mineral soil may contain a combination of fragment or composition types for which the use of compound texture modifiers is useful.
- For example, a soil horizon may contain both artifacts and other fragments, such as rock fragments and pararock fragments.
- In these cases, the rock fragments, pararock fragments, and artifacts are each described separately.
- Modifiers for both artifacts and rock or pararock fragments can be combined.
- The modifier for artifacts comes before the modifier for rock or pararock fragments, e.g., artifactual very gravelly sandy loam.
- Modifiers for composition and rock fragments can also be combined.
- For example, a horizon of channery mucky clay or one of gravelly gypsiferous sandy loam contains rock fragments and also a content of high organic matter or gypsum.
- There are many possible combinations.

Fragments on the Surface

- This section discusses the description of rock fragments (especially stones and boulders) that are on the soil as opposed to in the soil.
- The description of gravel, cobbles, and channers (≥ 2 but < 250 mm in diameter) differs from that for stones and boulders (≥ 250 mm in diameter) because an important aspect of gravel, cobbles, and channers is their areal percent cover on the ground surface.
- This cover provides some protection from wind and water erosion.
- It may also interfere with seed placement and emergence after germination.
- For stones and boulders, the percent of cover is not of itself as important as the interference with mechanical manipulation of the soil.
- For example, a very small areal percentage of large fragments, insignificant for erosion protection, may interfere with tillage, tree harvesting, and other operations involving machinery.

- The areal percentage of the ground surface is determined using pointcount and/or line-intersect procedures.
- If the areal percentage equals or exceeds 80 percent, the top of the soil is considered to be the mean height of the top of the rock or pararock fragments.
- The volume proportions of the 2 to 5 mm, 5 to 75 mm, and 75 to 250 mm fragments should be recorded.
- This can be done from areal measurements in representative areas.

- The number, size, and spacing of stones and boulders (≥ 250 mm in diameter) on the surface of a soil, including both those that lie on the surface and those that are partly within the soil, have important effects on soil use and management.
- The classes are given in terms of the approximate amount of rock fragments of stone and boulder size at the surface:
  - Class 1: Stones or boulders cover 0.01 to less than 0.1 percent of the surface.
    - The smallest stones are at least 8 meters apart; the smallest boulders are at least 20 meters apart.

Figure 9: An area of bouldery soil (class 1).
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- Class 2: Stones or boulders cover 0.1 to less than 3 percent of the surface.
  - The smallest stones are not less than 1 meter apart; the smallest boulders are not less than 3 meters apart.

Figure 10: An area of very bouldery soil (class 2).
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- Class 3: Stones or boulders cover 3 to less than 15 percent of the surface.
  - The smallest stones are as little as 0.5 meter apart; the smallest boulders are as little as 1 meter apart.

Figure 11: An area of extremely bouldery soil (class 3).
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- Class 4: Stones or boulders cover 15 to less than 50 percent of the surface.
  - The smallest stones are as little as 0.3 meter apart; the smallest boulders are as little as 0.5 meter apart.
  - In most places it is possible to step from stone to stone or jump from boulder to boulder without touching the soil.

Figure 12: An area of rubbly soil (class 4).
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- Class 5: Stones or boulders appear to be nearly continuous and cover 50 percent or more of the surface.
  - The smallest stones are less than 0.03 meter apart; the smallest boulders are less than 0.05 meter apart.
  - Classifiable soil is among the rock fragments, and plant growth is possible.

Figure 13: An area of very rubbly soil (class 5).
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

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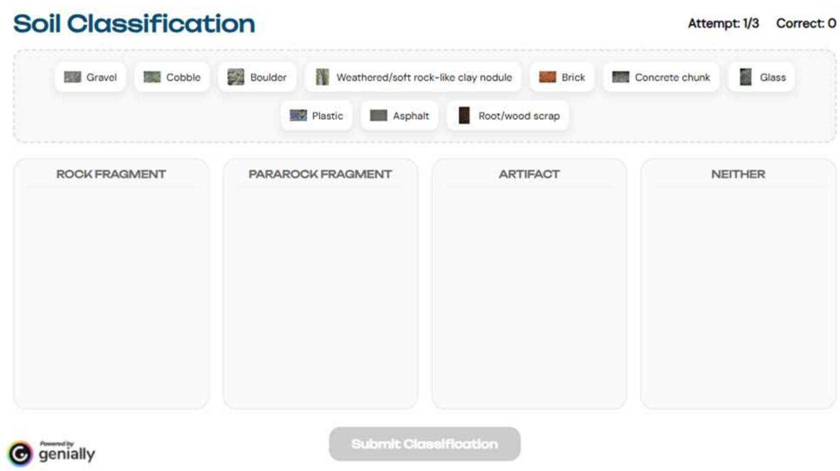
- These limits are intended only as guides to amounts that may mark critical limitations for major kinds of land use.
- The table here is a summary of the classes.

Class	Percentage of surface covered	Distance in meters between stones or boulders if the diameter is:			Descriptive term
		0.25 m*	0.6 m	1.2 m	
1	0.01 to < 0.1	≥ 8	≥ 20	≥ 37	Stony or bouldery
2	0.1 to < 3.0	1–8	3–20	6–37	Very stony or very bouldery
3	3.0 to < 15	0.5–1	1–3	2–6	Extremely stony or extremely bouldery
4	15 to < 50	0.3–0.5	0.5–1	1–2	Rubbly
5	≥ 50	< 0.3	< 0.5	< 1	Very rubbly

* 0.38 m if the fragment is flat.

Table 4: Classes of Surface Stones and Boulders in Terms of Cover and Spacing.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)



Soil Color

- Most soil survey organizations, including the National Cooperative Soil Survey in the United States, have adopted the Munsell soil color system for describing soil color (using the elements of hue, value, and chroma).
- The names associated with each standard color chip (yellowish brown, light gray, etc.) are not strictly part of the Munsell color system.
- They were selected by the Soil Survey Staff to be used in conjunction with the Munsell color chips.

- The color chips included in the standard soil-color charts (a subset of all colors in the system) were selected so that soil scientists can describe the normal range of colors found in soils.
- These chips have enough contrast between them for different individuals to match a soil sample to the same color chip consistently.
- Interpolating between chips is not recommended in standard soil survey operations because such visual determinations cannot be repeated with a high level of precision.
- Although digital soil color meters that can provide precise color readings consistently are available, they are not widely used in field operations.
- Therefore, the standard procedure adopted for soil survey work is visual comparison to the standard soil-color charts.

Elements of Soil Color Descriptions

- Elements of soil color descriptions are the color name, the Munsell notation, the water state (moist or dry), and the physical state.
- An example is “brown (10YR 5/3), dry, crushed and smoothed.”
- Physical state is recorded as broken, rubbed, crushed, or crushed and smoothed.
- The term “crushed” typically applies to dry samples and “rubbed” to moist samples. If physical state is unspecified, a broken surface is implied.
- The color of the soil is normally recorded for a surface broken through a ped, if a ped can be broken as a unit.
- If ped surfaces are noticeably different in color from the ped interior, this should also be described.

- The color value of most soil material is lower after moistening. Consequently, the water state of a sample is always given.
- The water state is either "moist" or "dry."
- The dry state for color determinations is air dry and should be made at the point where the color does not change with additional drying.
- Color in the moist state is determined on moderately moist or very moist soil material and should be made at the point where the color does not change with additional moistening.

- The soil should not be moistened to the extent that glistening takes place because the light reflection of water films may cause incorrect color determinations.
- In a humid region, the moist state generally is standard; in an arid region, the dry state is standard.
- In detailed descriptions, colors of both dry and moist soil are recorded if feasible.
- The color for the regionally standard moisture state is typically described first.
- Both moist and dry colors are valuable, particularly for the immediate surface and tilled horizons, in assessing reflectance.

- A Munsell notation is obtained by comparison with a Munsell soil-color chart.
- The most commonly used charts include only about one fifth of the entire range of hues.
- They consist of about 250 different colored papers, or chips, systematically arranged on hue cards according to their Munsell notations.
- The figure on the following slide illustrates the arrangements of color chips on a Munsell color card.
- The Munsell color system uses three elements of color—hue, value, and chroma.
- The color notation is recorded as: hue, value/chroma (e.g., 5Y 6/3).

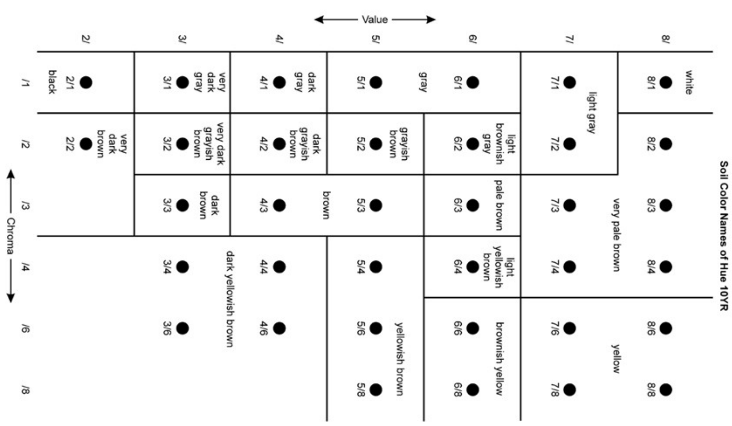


Figure 14: The arrangement of color chips according to value and chroma on the Munsell soil-color card of hue 10YR.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- Hue is a measure of the chromatic composition of light that reaches the eye.
- The Munsell system is based on five principal hues: red (R), yellow (Y), green (G), blue (B), and purple (P).
- Five intermediate hues representing midpoints between each pair of principal hues complete the 10 major hue names used to describe the notation.
- The intermediate hues are yellow-red (YR), green-yellow (GY), blue-green (BG), purple-blue (PB), and red-purple (RP).

- The relationships among the 10 hues are shown in the figure on the following slide.
- Each of the 10 major hues is divided into 4 segments of equal visual steps, which are designated by numerical values applied as prefixes to the symbol for the hue name.
- For example, 10R marks a limit of red hue.
- Four equally spaced steps of the adjacent yellow-red (YR) hue are identified as 2.5YR, 5YR, 7.5YR, and 10YR, respectively.
- The standard chart for soil has separate hue cards, from 10R through 5Y.
- In addition, special charts for gley colors and for very light colors are available.

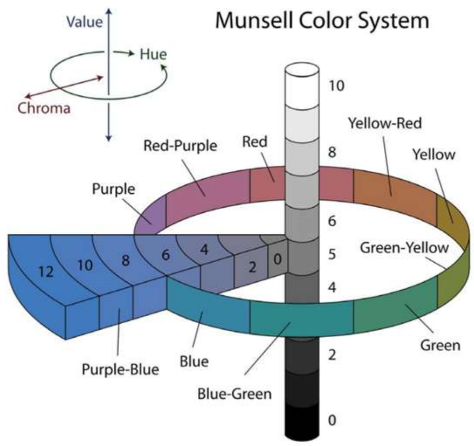


Figure 15: A schematic diagram showing relationships among hue, value, and chroma in the Munsell color system.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- Value indicates the degree of lightness or darkness of a color in relation to a neutral gray scale.
- On a neutral gray (achromatic) scale, value extends from pure black (0) to pure white (10).
- The value notation is a measure of the amount of light that reaches the eye under standard lighting conditions.
- Gray is perceived as about halfway between black and white and has a value notation of 5.

- The actual amount of light that reaches the eye is related logarithmically to color value.
- Lighter colors are indicated by numbers between 5 and 10; darker colors are indicated by numbers from 5 to 0.
- These values may be designated for either achromatic (i.e., having no hue and chroma of 0) or chromatic (i.e., having all three components—hue, value, and chroma) conditions.
- Thus, a card of the color chart for soil has a series of chips arranged vertically to show equal steps from the lightest to the darkest shades of that hue.
- Figure 14 shows this arrangement vertically on the card for the hue of 10YR.
- Note that the highest value shown on the standard color cards is 8.
- Color chips with value of 9 are included on special color cards for very light colors.

- Chroma is the relative purity or strength of the spectral color.
- It indicates the degree of saturation of neutral gray by the spectral color.
- The scales of chroma for soils extend from 0 (for neutral colors) to 8 (for colors with the strongest expression).
- The color chips are arranged horizontally by increasing chroma from left to right on the soil-color chart.
- On the soil-color chart for a specific hue (e.g., 10YR), the darkest shades of that hue are at the bottom of the card and the lightest shades are at the top.
- The weakest expression of chroma (the grayest color) is at the left, and the strongest expression of chroma is at the right.
- At the extreme left of some cards are symbols such as N 6/.
- These colors have zero chroma and are totally achromatic (neutral).
- They have no hue and no chroma but range in value from black (N 2.5/) to white (N 8/).
- An example of a notation for a neutral (achromatic) color is N 5/ (gray).
- The color 10YR 5/1 is also called gray because the hue is hardly perceptible at such low chroma.

Conditions for Measuring Color

- The quality and intensity of the light source affect the amount and quality of the light reflected.
- The moisture content of the sample and the roughness of its surface affect the light reflected.
- The visual impression of color from the standard color chips is accurate only under standard conditions of light intensity and quality.
- Color determination may be inaccurate early in the morning or late in the evening.
- When the sun is low in the sky or the atmosphere is smoky, the light reaching the sample and the light reflected are redder.
- Even though the same kind of light reaches the color standard and the sample, the reading of sample color at these times is commonly one or more intervals of hue redder than at midday.
- Colors also appear different in the subdued light of a cloudy day than in bright sunlight. If artificial light is used, as for color determinations in an office, the light source must be as near the white light of midday as possible.
- With practice, compensation can be made for the differences.
- The intensity of incidental light is especially critical when matching soil to chips of low chroma and low value.

- Roughness of the reflecting surface affects the amount of reflected light, especially if the incidental light falls at an acute angle.
- The incidental light should be as near as possible at a right angle.
- For crushed samples, the surface is smoothed and the state is recorded as "dry, crushed and smoothed."

Guidelines for Recording Color

Uncertainty

- Under field conditions, measurements of color are reproducible by different individuals within 2.5 units of hue (one Munsell soil-color chart) and 1 unit of value and chroma.
- Notations are made to match the chips included on the color charts, typically the nearest whole unit of value and chroma.
- Soil color should be recorded to the closest color chip provided but not interpolated between chips.
- For some hues, chips for value of 2.5 are included.

- Determinations typically are not precise enough to justify interpolation between chromas of 4 and 6 or between chromas of 6 and 8.
- Color should never be extrapolated beyond the highest chip.
- The soil-color charts for individual hues do not show value greater than 8.
- However, chips with higher values are included on a special “white” chart and should be used for soils with very light colors (e.g., those with a high content of calcium carbonate).
- Observed colors are always rounded to the nearest chip.
- For many purposes, the differences between colors of some adjacent color chips have little significance.
- For these, color notations have been grouped and named.

Dominant Color

- The dominant color is the one that occupies the greatest layer volume.
- It is always listed first among the colors of a multicolored layer.
- It is determined using the colors on ped faces or broken peds or on a matrix sample in structureless horizons.
- If two colors occur, the dominant color makes up more than 50 percent of the volume.
- If three or more colors are noted, the dominant color makes up more of the layer volume than any other color, although it may occupy less than 50 percent.
- The expression "brown with yellowish brown and grayish brown" signifies that brown is the dominant color and may, or may not, make up more than 50 percent of the layer.

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- In some layers, no single color is dominant and the first color listed is not more prevalent than others.
- The expression "brown and yellowish brown with grayish brown" indicates that brown and yellowish brown make up about equal amounts and are codominant.
- If the colors are described as "brown, yellowish brown, and grayish brown," the three colors make up nearly equal parts of the layer.

Other Non-Matrix Colors

- In addition to either a single dominant matrix color or two or more codominant matrix colors, other non-matrix colors may be present.
- Non-matrix colors are generally related to one of the following four situations:
  - 1. The additional colors are associated with a ped or void surface feature (such as clay films, silt coatings, slickensides, etc.).
  - 2. The colors are associated with concentrations in the soil (such as plinthite, calcium carbonate, gypsum crystals, etc.).
  - 3. The colors are due to oxidation and/or reduction processes in wet soil (i.e., redoximorphic features, such as iron masses, iron depletions, and manganese nodules).
  - 4. The color is inherited from the parent material and is not the result of pedogenic processes.
    - These colors are lithochromic or lithomorphic and described as mottles.
- Protocols for describing redoximorphic features, surface features, and concentrations in the soil (including color) are presented later in this chapter.

Mottling

- Mottling refers to repetitive color changes that cannot be associated with compositional properties of the soil.
- As described previously, a color pattern related to a ped surface or other organizational or compositional feature is not mottling.
- In horizon description, mottle description follows dominant color. Mottles (and other non-matrix features) are described by quantity, size, contrast, color, and, if important, other attributes such as moisture state, shape, and location, in that order

- Quantity is indicated by three areal percentage classes of the observed surface:
  - Few less than 2 percent
  - Common 2 to less than 20 percent
  - Many 20 percent or more
- The notations must clearly indicate the colors to which the terms for quantity apply.
- For example, "common grayish brown and yellowish brown mottles" could mean that each color makes up 2 to 20 percent of the horizon.
- By convention, the example is interpreted to mean that the quantity of the two colors together is between 2 and 20 percent.
- If each color makes up between 2 and 20 percent, the description should be "common grayish brown (10YR 5/2) and common yellowish brown (10YR 5/4) mottles."

- Size refers to dimensions as seen on a plane surface.
- If the length of a mottle is not more than two or three times the width, the dimension recorded is the greater of the two.
- If the mottle is long and narrow, as a band of color at the periphery of a ped, the dimension recorded is the smaller of the two and the shape and location are also described.
- Five size classes are used to describe mottles:
  - Fine smaller than 2 mm
  - Medium 2 to less than 5 mm
  - Coarse 5 to less than 20 mm
  - Very coarse 20 to less than 76 mm
  - Extremely coarse 76 mm or more

- Contrast refers to the degree of visual distinction that is evident between associated colors.
- The criteria for determining contrast class are given in table 5.
- The classes for color contrast are:
  - Faint: Color is evident only on close examination.
  - Distinct: Color is readily seen but contrasts only moderately with the color to which it is compared.
  - Prominent: Color contrasts strongly with the color to which it is compared.
    - Prominent colors are commonly the most obvious color feature of the section described.
- Contrast is often not a simple comparison of one color with another but is a visual impression of the prominence of one color against a background of several colors.

Contrast class	Difference between compared colors			
	Hue	Value		Chroma
Faint*	0;	≤ 2	and	≤ 1
	1;	≤ 1	and	≤ 1
	2;	0	and	0
Distinct*	0;	≤ 2	and	> 1 to < 4
			or	
		> 2 to < 4	and	< 4
	1;	≤1	and	> 1 to < 3
			or	
		> 1 to < 3	and	< 3
	2;	0	and	> 0 to < 2
			or	
		0 to < 2	and	< 2
Prominent*	0;	≥ 4	or	≥ 4
	1;	≥ 3	or	≥ 3
	2;	≥ 2	or	≥ 2
	3			

* If the compared colors have both a value ≤ 3 and a chroma ≤ 2, the contrast is faint, regardless of hue differences.

Table 5: Color Contrast Class Terms and Their Criteria.
(Source: USDA, "Soil Survey Manual", March 2017, USDA Handbook 18)

- Mottles and other features (if significant) are described using terms for shape, location, and boundary character.
  - Shape: These terms are the same as those used for other concentrations in the soil (i.e., cylindrical, platy, reticulate, etc.).
  - Location: The location of the mottles relative to structure of the soil is described.
  - Boundary classes: Terms are as follows:
    - Sharp: Color grades over less than 0.1 mm.
      - Gradation is barely discernable or not discernible by the naked eye, but visible under a 10X lens.
    - Clear: Color grades over more than 0.1 mm but less than 2 mm.
      - Gradation can be obscure but visible to the naked eye. A 10X lens is not required.
    - Diffuse: Color grades over 2 mm or more.
      - Gradation is easily discernable by the naked eye.
      - A 10X lens is not required.

- Moisture state and physical state of the dominant color are presumed to apply to the mottles unless the description states otherwise.
- For example, the description of a sample with a specified standard moist broken state may be "brown (10YR 4/3), brown (10YR 5/3) dry; many medium distinct yellowish brown (10YR 5/6) mottles, brownish yellow (10YR 6/6) dry."
- Alternatively, the colors in the standard moisture state may be given together, followed by the colors in other moisture states.
- The color of mottles commonly is given only for the standard state unless colors in another state have special significance.

- An example of a description of a sample with a nearly equal mixture of two colors for a moist broken standard state is "intermingled brown (10YR 4/3) and yellowish brown (10YR 5/6) in a medium distinct pattern; brown (10YR 5/3) and brownish yellow (10YR 6/6) dry."
- If a third color is present, it can be added, for example, "common medium faint dark grayish brown (10YR 4/2) mottles, grayish brown (10YR 5/2) dry."
- If the mottles are fine and faint and cannot be compared easily with the color standards, the Munsell notation should be omitted.
- Other abbreviated descriptions are used for specific circumstances.

Color Patterns Within the Soil

- Color may be recorded separately for features that merit a distinct description, especially for redoximorphic features but also for peds, concretions, nodules, cemented bodies, filled animal burrows, etc.
- Color patterns that exhibit a spatial relationship to composition changes or to features, such as nodules or surfaces of structural units, are useful in descriptions because they can infer genesis and soil behavior.
- Colors may be given for extensions of material from another soil layer.
- For example, the fine tubular color patterns that extend vertically below the A horizon of some wet soils were determined by the environment adjacent to roots that once occupied the tubules.
- The relationship of redoximorphic features to locations in the horizon (such as ped faces, ped interiors, pore linings, etc.) provides important clues about internal patterns of wetness.
- For example, a rim of bright color around an inner zone of lighter color at the surface of some peds relates to water movement into and out of the peds and to oxidation-reduction relationships.

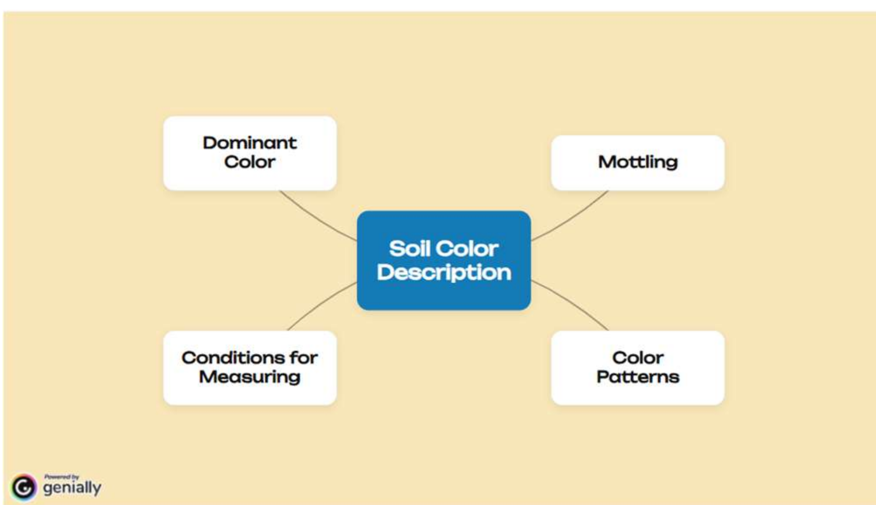
Ground Surface Color

- The ground surface color has an important effect on heat transmission into the soil.
- Albedo (the ratio of the reflected incident short-wave solar radiation to the total amount received) is related to soil color, especially value.
- It is an essential parameter for estimating evapotranspiration and for calculating water balance for hydrological models.
- The color value of the immediate ground surface may differ markedly from that of the surface horizon.
- For example, raindrop impact that removed clay-sized material from the surface of sand and silt particles may result in a thin surface crust about a millimeter thick with higher color value.
- Albedo for the fine-earth soil component of the surface cover (given the surface is smooth) can be estimated with the equation:

$$\text{albedo} = 0.069 * (\text{value dry}) - 0.114$$

- Specialized studies involving model inputs that include albedo use color information for the total ground surface, including vegetation as well as soil material.
- In some arid soils, dark rock fragments may have reduced the color value of the ground surface appreciably from that of the fine earth of the surface horizon as a whole.
- Furthermore, dead vegetation may have color values that differ appreciably from those for the fine earth of the surface horizon.
- Surface color influences reflectivity of light, which influences the capacity to absorb and release radiant energy.

- Soil surface colors at a given site commonly range widely due to the presence of more than one kind of cover.
- It may be necessary to estimate the areal proportion of the color value for each ground surface type separately (such as rock fragments, dead vegetation, or fine earth), and then select a single color value for each important ground surface component.
- From the areal proportion of the components and their color value, a weighted average color value for the ground surface may be computed.



THANK YOU FOR LISTENING!

This concludes our presentation, and we hope that you enjoyed it.

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REFERENCES

This interactive presentation was adapted from Chapter 3 of the document by the Unified States Department of Agriculture (USDA), Soil Survey Manual, March 2017, USDA Handbook 18.

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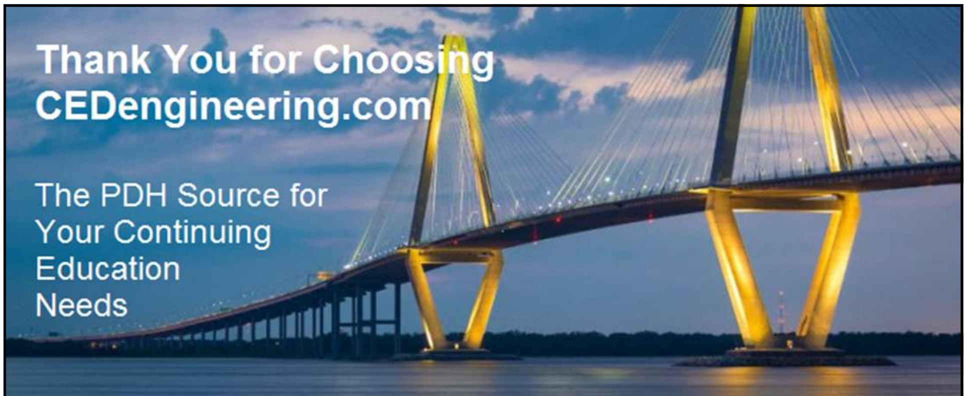

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