United States Department of Agriculture

Illustrated Guide to Soil Taxonomy

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Natural
Resources
Conservation
Service

Foreword

The “Illustrated Guide to Soil Taxonomy” is intended for use by multiple audiences. First, it is designed to help college students who have some background in soil science, and especially those participating on collegiate soil judging teams, to learn the fundamental concepts of soil classification. Second, it is for professionals who use soil survey information in their work, such as soil conservationists, agronomists, rangeland specialists, foresters, and engineers. The narrative descriptions for the soil orders, suborders, and great groups can help them to understand the broad concepts of soil classification. In addition, definitions of many of the diagnostic horizons and features are accompanied by photos and background information. This can help the professional to understand the importance of these horizons and features and how they relate to their work. Third, the guide is for soil scientists beginning a career in soil survey. Its presentation of basic concepts will be helpful in their work, especially as they encounter new kinds of soil taxa.

This document is not intended to replace the full version of the “Keys to Soil Taxonomy” for the professional soil classifier. Although the authors estimate that the use of this version will result in the proper great group classification in approximately 90 percent of the cases in which it is used, the guide is not fully sufficient for correct placement in all cases. In this guide, some of the more technical and complicated criteria have either been omitted entirely or simply alluded to in notes which alert the user that exceptions or more complete definitions are only provided in the full version of the keys. To ensure proper application of the criteria for classifying soils, the latest version of the “Keys to Soil Taxonomy” is needed. In addition, this guide omits all information needed to classify soils to the subgroup and family levels, which are essential categories in soil survey work.

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Contents

Part 1—How to Use This Version of the Keys

Part 2—Horizon Nomenclature Used for Describing Soil Profiles

Part 3—Diagnostic Horizons and Characteristics

Part 4—Keys to the Orders, Suborders, and Great Groups

Part 1—How to Use This Version of the Keys

Introduction

The “Illustrated Guide to Soil Taxonomy” is presented in four parts, each covering a specific aspect of the USDA’s soil classification system (Soil Taxonomy). It is a PDF document designed for use on a PC, tablet, or smart phone. Each part contains many internal links, and bookmarks are provided for the major items in each part.

Part 1—How to Use This Version of the Keys

This part has five main sections:

- An overall summary of each part of the guide.
- A brief discussion of the general steps to follow when classifying a soil.
- A list of a few things to know about classifying soils. This information needs to be understood and followed when using these keys.
- A discussion of soil moisture and temperature regimes. This section includes generalized maps of the continental United States that can be used to estimate the correct class based on location in the country.
- A brief list of important sources of information along with a list of abbreviations and acronyms. The sources can be used to find more in-depth definitions or explanations of the terms and concepts presented in any of the parts.

Part 2—Horizon Nomenclature Used for Describing Soil Profiles

This part provides a brief description of the master horizon designations, letter suffixes, number prefixes and suffixes, special symbols, and conventions for using standard horizon nomenclature to describe soil profiles. In addition to background information and basic conventions for using the nomenclature, Part 2 provides tables that list the master horizon symbols (table 1) and the subordinate suffix symbols (tables 2A and 2B) and give a general description of each.

Part 3—Diagnostic Horizons and Characteristics

This part has two major sections. In the first section, the eight diagnostic surface horizons (“epipedons”) are presented. In the second section, 49 diagnostic horizons and characteristics are presented. A diagnostic horizon constitutes a continuous horizon in the soil profile. Diagnostic characteristics are features found within some horizons (e.g., plinthite or slickensides) but that do not form a continuous layer in the soil profile. This part discusses only those needed to classify a soil to the great group level (for more, see the current edition of the “Keys to Soil Taxonomy”). It also includes information on each of the soil moisture and soil temperature regimes. For each diagnostic horizon or feature presented, the following is provided:

- **Heading.** A brief descriptive phrase is given for the item.
- **Concept and background information.** A brief narrative describes the concept of the item and gives basic information.
- **Generalized characteristics.** The criteria given in the “Keys to Soil Taxonomy,” 12th edition, are presented in a somewhat simplified and illustrated version. Information has been reworded, and, in a few cases, the critera have been reorganized. Some of the more complex details have been omitted. Generally, a note (italicized text that follows) alerts the reader if there are exceptions to the presented information or if additional information is available in the full version of the keys.
- **Common horizon nomenclature.** The master horizon and/or subordinate symbols that are commonly used in soil descriptions to indicate a particular diagnostic horizon or characteristic are identified.
- **Photos** (for most of the diagnostic horizons and characteristics)

Part 4—Keys to the Orders, Suborders, and Great Groups

This part is an illustrated and somewhat simplified version of the keys to the orders, suborders, and great groups. Narrative descriptions are provided for each category.

Keys to the twelve soil orders and their suborders and great groups

The full version of the keys is somewhat simplified. Information has been reworded, and, in a few cases, the criteria have been reorganized. Some of the more complex details have been omitted. Generally, a note (italicized text that follows) alerts the reader if there are exceptions to the presented information or if additional information is available in the full version of the keys.

The last choice in each key has been modified to include one or more diagnostic horizons or properties present in the soil profile. This is a potentially significant change from the “Keys to Soil Taxonomy,” in which the last choice is simply listed as “all others.” Because of this change, it is possible that a soil profile will be impossible to classify using this guide.

Narratives for each order

The one-page narrative includes the following:

- **Heading.** A brief descriptive phrase is given for the basic concept of the soil order.
- **General characteristics.** These are the major horizons and properties associated with the order.

- **Environment and processes.** The kind of environments where the order occurs and some important processes and characteristics of these environments are discussed.
- **Location**. The places where the soils occur in the world and in the United States are identified.
- **Photo.** An image of the soil profile representing the order is provided.
- **Maps**. These depict the distribution of the soils globally and within the United States.
- **Brief narrative.** The main soil properties and features considered at the suborder and great group level of classification are discussed.

Charts for each order and suborder

A graphical depiction, in the form of a hierarchical chart, shows (in keying order) the suborders within the order and the great groups within the suborder.

Descriptions for each suborder and great group

A narrative description describes the important features of the suborder or great group (arranged in alphabetical order). For some classes, a representative photo is also included.

General Steps to Follow When Classifying a Soil

1. Consider the environment where the soil profile is located. By considering the soil-forming processes most likely occurring at the site, you can begin to narrow your focus to the soil features most likely to be present. This includes considering both the broad physiographic region as well as the position on the local landscape. Based on these two factors, consider the kinds of soil processes likely to be important in the area and the types of diagnostic horizons and features that may be present. For example, if you are on the prairies of the Northern Plains, it is likely that organic matter accumulation has been an important soil-forming process and that a mollic epipedon is present. If you are in the Mohave Desert, the accumulation of soluble compounds due to little or no leaching is likely to be a more prominent process than organic matter accumulation. In this area, diagnostic horizons (such as calcic, gypsic, natric, or salic subsoil horizons) are more likely to occur than a mollic epipedon or a spodic horizon.

Consider the local landscape. For example, soils on broad upland divides may have well developed, thick subsoil horizons reflecting a fairly stable landform, while soils on adjacent steep side slopes, assuming that the overall processes of erosion are more or less keeping pace with the processes of soil development, probably are less well developed. Soils in concave positions tend to receive additional runoff water from adjacent slopes while those on convex slopes tend to shed water. This may lead to wetness in the concave areas and the formation of redoximorphic features.

A useful source of information about the soils in many areas is the most recently published USDA-NRCS soil survey report (if one exists for the area). The chapter on formation of the soils can be particularly helpful in understanding the overall soil-forming processes in the area and in learning which moisture and temperature regimes have been identified for the area.

2. Describe the soil profile. A complete and accurate soil profile description is essential for classifying the soil. A previously prepared standard form is useful because it will help you to record all of the important information. An example of a standard pedon description form can be found in the "Field Book for Describing and Sampling Soils" (pages 2-93 and 2-94). Also, part 2 of this guide provides information on the standard nomenclature for describing soil horizons. Click here to see a video about describing soil horizons in the field. Click here to see a video describing how to use the "Field Book for Describing and Sampling Soils."

Begin by observing the exposed profile as a whole. Is any part composed of organic soil material? If so, those parts will be named as O horizons. With respect to the lower part, is there evidence of soil development all the way to the bottom? Consider features such as structure, color, and presence of clay films. If soil development does not extend to the bottom of the profile, mark where the solum ends and the underlying parent material (i.e., C horizon) begins. Next, consider the top part of the profile. Mark the lower boundary of the epipedon. Most likely it is at least slightly darkened by organic matter accumulation. Now consider the zone under the epipedon and above the C horizon or the lower boundary of the soil (i.e., a Cr or R layer, if present). Is this a B horizon only, or do you see an E horizon (light-colored, leached layer)? Mark these major divisions, as appropriate.

Finally, look more closely at each of the major divisions you have identified. Consider the features that are present and relate them to the horizon nomenclature used for describing soils. For example, if one or more layers of the B horizon have clay films, the suffix "t" is needed. If a horizon is engulfed by secondary calcium carbonate to such an extent that it will not slake in water (continuously cemented) and is root restrictive, the suffix "kkm" is appropriate. In this way, you document the kinds of soil processes based on the morphology that you observe in the profile.

Soil scientists describing a soil profile in the United Arab Emirates. (Photo courtesy of Dr. Craig Ditzler)

3. **Determine which diagnostic horizons and characteristics are present**. Using the information provided in part 3 of this guide, determine which diagnostic horizons and characteristics are present and record their location in the profile (e.g., mollic epipedon, 0-40 cm, redoximorphic features 60-200 cm, etc.). Remember that the diagnostic horizons and characteristics are not a part of a sequential key and, because most profiles have more than one, you need make certain to identify all horizons and characteristics that apply. To do this accurately, laboratory data probably will be needed for the horizons described. If data cannot be provided, sampling and analysis may be needed. In the absence of data, educated assumptions will be required based on knowledge and past experience with similar soils in the area. Although Soil Taxonomy recognizes many diagnostic horizons and characteristics, only a few are likely to occur in a specific profile.

4. Identify the soil moisture and temperature regimes. It is likely that the classification at the suborder or great group level will require determination of the soil moisture regime and possibly the soil temperature regime. If no data exist, see the information on these topics provided later in this part of the guide (part 1).

5. Determine the classification. Using part 4 of this guide, determine the correct order, suborder, and great group for the soil. Keep in mind that the keys are designed to be used in sequential order. Begin with the key to the orders. Once a set of criteria is met, stop and go to the section for that order. Following the key to suborders, start at the top and work down sequentially to the first suborder where all criteria are met. Do the same to determine the proper great group.

A Few Things to Know About Classifying Soils

Sequential use of the keys. The keys are designed to be used sequentially, beginning with the key to the orders, then the suborders, and finally the great groups. Start with the first item listed in the key to orders and evaluate the soil to see if it meets the criteria. If the initial criteria listed are not met, continue through the key until the criteria are met. Once you determine that the criteria for the order are met, move on to suborder and finally great group. *The design of the keys is such that the soil is to be placed in the first taxa for which the criteria are met.*

Operational definitions. Many of the criteria that define diagnostic horizons or that are used as class limits in the keys require evaluation of a measured physical or chemical property. Examples include bulk density, base saturation, clay content, effective cation-exchange capacity, electrical conductivity, organic carbon, pH, and content of weatherable minerals. The values obtained in the laboratory for these properties are dependent on the method used to measure the property. Consider clay content. It can be measured in the laboratory by the hydrometer method or by the pipette method. Values obtained by each method on a given sample will be similar, but not identical.

Soil Taxonomy uses “operational definitions” tied to specific measurement methods to define the properties used as class limits. In the case of clay content, criteria are based data gained by the pipette method. The appendix included at the end of the current version of the “Keys to Soil Taxonomy” provides a discussion of the properties and methods. Specific information regarding the analytical procedures is contained in the “Soil Survey Laboratory Methods Manual.” Additional information is available in the “Soil Survey Laboratory Information Manual.”

Rounding. When evaluating data to see if a criterion has been met, normal rules for rounding should be applied. For example, item 2 for Vertisols in the keys to the soil orders uses a class limit of $\geq$ 30% clay. Note that a whole number is used. Therefore, if laboratory results show a clay content of 29.6%, you first round to 30% and then determine that the requirement is in fact met. Similarly, item 1 for Ultisols in the key to the soil orders lists a requirement that base saturation (by sum of bases) be < 35%. For example, a measured base saturation of 34.7% is rounded to 35%, and the criterion is therefore not met (exactly 35% fails the criteria as given). Therefore, *when measured data is applied to classifying the soil, one must first note the level of precision used as a class limit and then round the measured data to the same level of precision.*

The conventional rules for rounding numbers are as follows:

- If the digit immediately to the right of the last significant figure is more than 5, round up to the next higher digit. For example, 34.8 is rounded to 35 (round up because the digit to be dropped is more than halfway between 34 and 35).
- If the digit immediately to the right of the last significant figure is less than 5, round down to the next lower digit. For example, 34.4 is rounded to 34 (round down because the digit to be dropped is less than halfway between 34 and 35).
- If the digit immediately to the right of the last significant figure is equal to 5, round to the adjacent even number, either up or down. For example, 17.5 is rounded to 18 (round up because the result is an even number) and 34.5 is rounded to 34 (round down because the result is an even number).

Soil color. An important criterion in many of the keys, as well as in the definitions of the diagnostic horizons and features, is soil color. The operational definition for soil color uses the Munsell Soil-Color Charts®. Hue, value, and chroma are identified for a soil sample. Colors are recorded to the closest matching color chip in the charts. The quality of light has an effect on the visual perception of color, so it is best to evaluate color outdoors in natural sunlight, neither too early nor too late in the day, and without wearing sunglasses. Soil moisture state can also influence the hue, value, or chroma observed for the soil (value is particularly susceptible to change in soil moisture state). Because of this, the keys often specify the moisture state (i.e., moist or dry) for the evaluation of color. However, in cases where moisture state is not specified, the criterion is met if the required color is observed either moist or dry. Further discussion of soil color can be found in chapter 3 of the “Soil Survey Manual.”

A soil scientist compares a hand sample from a horizon within a soil profile to a standard color chip in the Munsell Soil-Color Charts®. (Photo courtesy of John Kelley)

Return to discussion on soil color.

Horizon designation and diagnostic horizons. It is a common misconception that there is equivalence between horizon designations and the presence of diagnostic horizons. For example, if a soil contains a subsoil horizon labeled Bt, it should not be assumed that this horizon is an argillic horizon. Similarly, a Bk horizon should not be assumed to be a calcic horizon. While many Bt horizons are in fact argillic horizons and many Bk horizons are calcic horizons, this is not always true. The guidelines for applying horizon designations are more qualitative than quantitative and thus allow the field observer to apply the symbolic designation that best fits his or her interpretation of the soil-forming processes. Diagnostic horizons are identified based on observable and measurable properties defining a class limit that must be met. For example, while an observer may note clay films in a layer, thus justifying the use of the symbol “Bt” to indicate illuvial clay, the layer may not be sufficiently thick, or the increase in clay content may not be great enough, to meet the minimum criteria for an argillic horizon.

Depths in the soil used for classification. It is important to know what part of the soil to consider when classifying a soil. Major points to remember when using these keys to classify a soil to the great group level are listed below. Additional considerations are required to classify to the family and series level.

1) The lower depth of consideration is arbitrarily limited to a maximum of 200 cm. This is simply a practical consideration to facilitate field operations in soil survey. This does not imply that soil descriptions below 200 cm are not valuable, but the properties observed below this depth are not considered in the classification.
2) Soil properties below any densic, lithic, paralithic, or petroferric contact are not considered when classifying a soil. This is so that the depth of consideration can be limited to less than 200 cm.
3) Application of these keys often requires one to determine the depth to a diagnostic horizon or feature, such as a petrocalcic horizon, permafrost, a lithic contact, redoximorphic features, and many others. In most soils, this simply means measuring from the soil surface (beginning below any fresh leaf or needle litter that is undecomposed) to the top of the diagnostic horizon, or to the depth where the feature in question begins. (Only the top of the horizon needs to be within the listed depth.) In cases where the depth to the upper boundary varies laterally (i.e., a wavy or irregular boundary), judgment must be used to select a value that best represents the observation of the soil. In cases where depth measurements start below any surface O horizon, the datum is noted in the keys as the "mineral soil surface."
4) An exception to item 3 is for cases in which a "surface mantle of new material" covers an older "buried soil." To be considered a surface mantle of new material covering a buried soil, the material must:
    a) Be at least 50 cm thick,
    b) Have a zone at least 7.5 cm thick at its base that fails the criteria for any diagnostic horizon, and
    c) Be underlain by an older soil with a sequence of one or more genetically developed horizons.

   Examples include: recent deposits, such as eolian sands, over a paleosol formed in till; a volcanic ash deposit blanketing a soil on a mountain slope; a landslide which buries an older soil on a stream terrace; and recently deposited fill material (human-transported material) covering the surface of a naturally occurring soil. In cases like these, two soils are potentially present: a new soil (such as an Entisol) covering an older one (such as an Alfisol). Which should be classified? To decide, one must determine if the older soil meets the definition of a "buried soil" (see chapters 1 and 4 of the "Keys to Soil Taxonomy").

   Case 1—The new material fails item *a* above (is less than 50 cm thick). Classify the older soil. Begin measuring from the older soil's surface (except in cases where soil temperature, soil moisture, and/or andic or vitrandic properties dictate otherwise).

Case 2—The new material meets items *a, b*, and *c*. Classify the new soil. Begin measuring from the new soil's surface. Any diagnostic horizons present in the buried soil are not considered in the classification for order, suborder, or great group. Use suffix "b" with any genetic horizons in the older soil.

Case 3—The new material fails item *b*. The materials are considered to be just one soil. Begin measuring from the new soil surface and consider all diagnostic horizons that are present within a depth of 2 m. The older soil is no longer considered "buried." Recognize a lithologic discontinuity for horizons below the contact between the new and old parent materials.

Case 4—The underlying (older) material fails item *c* (has no genetic horizons). As in case 3, the materials are considered just one soil. Begin measuring from the new soil surface.

For a more in-depth discussion, including example photos explaining how to identify a surface mantle and a buried soil, see Soil Survey Technical Note No.10 (Buried Soils and Their Effect on Taxonomic Classification).

Soil Moisture and Temperature Regimes

Soil Moisture Regimes

Many of the suborders and some great groups are defined by the moisture regime of the soil. The soil moisture regimes are defined by conditions within the moisture control section (MCS).The upper boundary of the MCS is the depth to which a dry soil will be wetted by 2.5 cm of precipitation in a 24-hour period. The lower boundary is the depth to which the same soil will be wetted by 7.5 cm of precipitation in a 48-hour period. Note that the MCS will vary depending on the porosity of the soil. As a general rule, the MCS will begin and end deeper in the profile as texture becomes progressively coarser, as follows:

Depth is 10-30 cm if the soil is loamy or clayey.
Depth is 20-60 cm if the soil is loamy with < ~18% clay and > ~15% sand.
Depth is 30-90 cm if the soil is sandy.
(Depth may be even greater for gravelly soils.)

The aridic (torric), udic, perudic, ustic, and xeric soil moisture regimes are defined by the number of days and seasonal patterns that the soil is either moist or dry in the MCS. The soil is considered dry if moisture is held at a tension $\geq$ 1500 kPa and moist if held at a tension < 1500 kPa (1500 kPa tension is commonly considered the wilting point). The aquic soil moisture regime requires the MCS to be periodically saturated and reduced, sometimes for as little as a few days in a year when the soil temperature is above 5 °C. The peraquic soil moisture regime is also a reducing regime that exists in soils which are continuously saturated to the soil surface (e.g., subaqueous soils). Specific criteria for each moisture regime are given in chapter 3 of the current "Keys to Soil Taxonomy."

The criteria (modified from the "Field Book for Describing and Sampling Soils," version 3.0) for each moisture regime are summarized here:

Aquic—A reducing regime for soils that are free of dissolved oxygen and saturated when the soil temperature is above 5 °C (seasonal ground-water fluctuations are typical). Unlike other regimes, the aquic regime may occur temporarily for only a few days. Since this regime is not defined on an annual basis, some soils with an aquic moisture regime also have a xeric, ustic, or aridic (torric) soil moisture regime. (*Note: The aquic moisture regime is not used as criteria in the keys. Instead, the presence of aquic conditions is used.*)

Aridic (Torric)—The predominantly dry regime for soils of arid and semiarid climates that are unsuitable for cultivation without irrigation. In most years, the soil is dry (in all parts of the soil moisture control section) > 50% of all days annually when the soil is > 5 °C at a depth of 50 cm and moist in some part for < 90 consecutive days when the soil is > 8 °C at a depth of 50 cm. Click here for an example of the seasonal pattern of precipitation and evapotranspiration in an area with the aridic soil moisture regime.

Udic—The predominantly moist regime for soils of humid climates with well distributed rainfall. In most years, the soil is dry (in any part of soil moisture control section) for < 90 cumulative days. Click here for an example of the seasonal pattern of precipitation and evapotranspiration in an area with the udic soil moisture regime.

Perudic—An extremely wet regime for soils of climates where precipitation exceeds evapotranspiration in all months in most years. The soil is almost always moist; soil tension is rarely > 100 kPa (≈ >1 bar). Click here for an example of the seasonal pattern of precipitation and evapotranspiration in an area with the perudic soil moisture regime.

Ustic—The temporarily dry regime for soils of climates that are intermediate between dry (aridic) and moist (udic). The soil is intermittently moist and dry; moisture is limited but usually available during portions of the growing season. In most years, the soil is moist > 180 cumulative days or > 90 consecutive days. Click here for an example of the seasonal pattern of precipitation and evapotranspiration in an area with the ustic soil moisture regime.

Xeric—The seasonally dry regime for soils of Mediterranean-type climates, which have cool, moist winters and warm, dry summers. In most years, the soil is moist in all parts for ≥ 45 consecutive days in the 4 months following the winter solstice (i.e., winter and early spring) and dry in all parts for ≥ 45 consecutive days in the 4 months following the summer solstice (i.e., summer and early fall). The soil is also moist in some part > 50% of all days when the soil is > 5 °C at a depth of 50 cm or moist in some part for ≥ 90 consecutive days when the soil is > 8 °C at a depth of 50 cm. Click here for an example of the seasonal pattern of precipitation and evapotranspiration in an area with the xeric soil moisture regime.

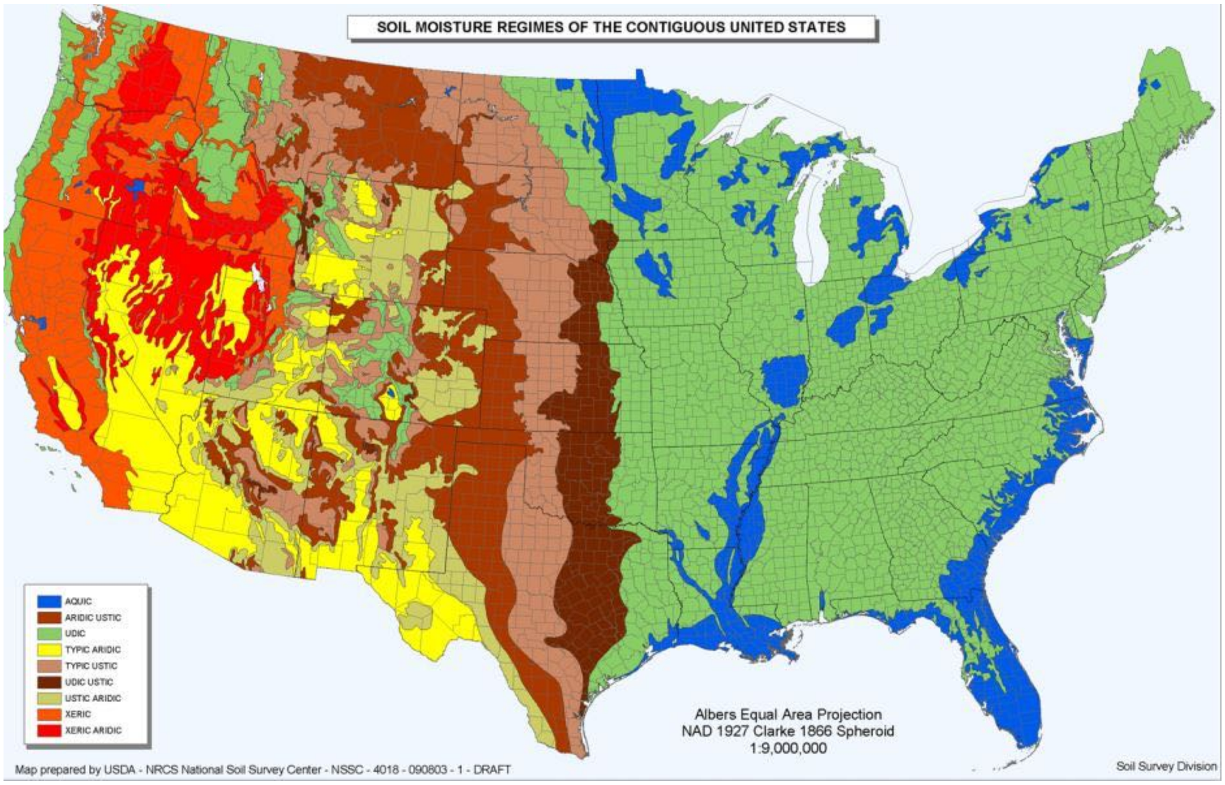
Determining the correct moisture regime class for a given soil can be difficult. There are three approaches:

1) The moisture state of the MCS is measured in the field using soil moisture sensors. This approach is done at selected sites and provides very valuable information. However, because it is expensive and time-consuming to collect the required multiple years of data, this approach generally is not practical for routine soil classification needs.

2) The expected moist/dry seasonal pattern for the moisture control section is determined with a computer simulation model. Inputs required include past temperature and precipitation data for the site and information about the water storage capacity of the soil profile to be modeled. The Java Newhall Simulation Model can be used for this.

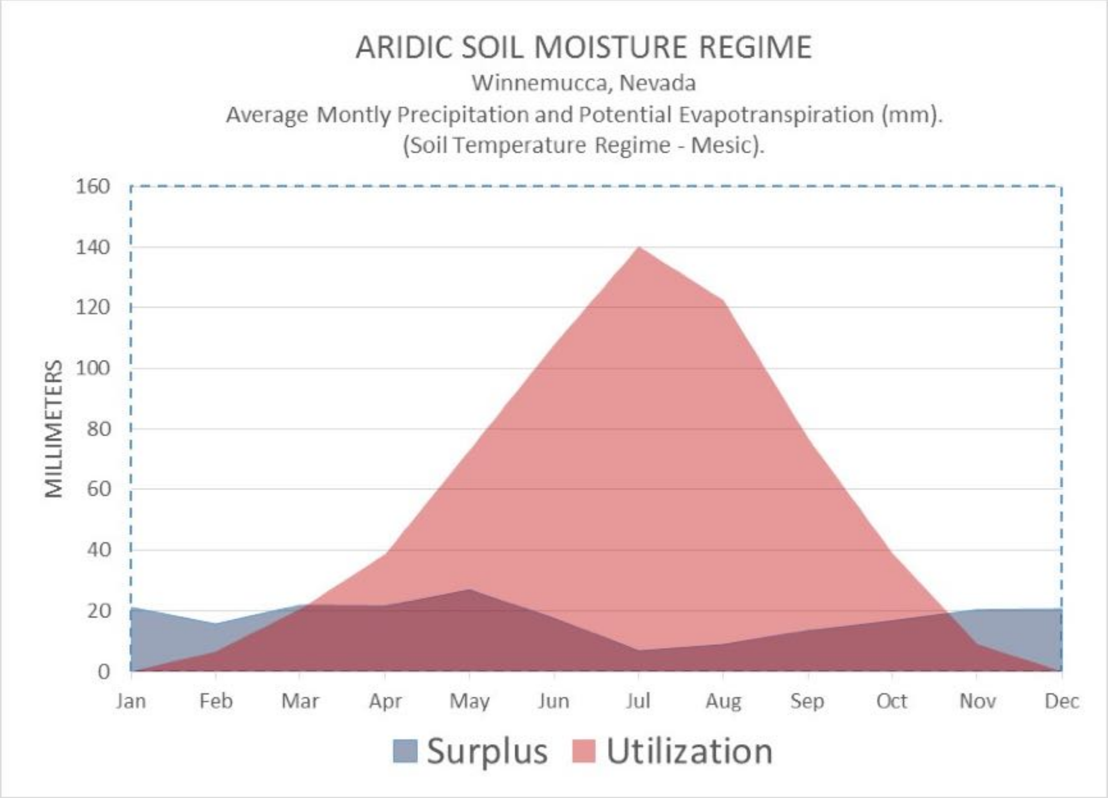
3) Where previous soil survey data collection and field experience are well documented, soil moisture regimes are inferred from geographic location (including general location in the country, elevation, aspect, and topographic relationships) as well as from knowledge of relationships between natural vegetation and moisture regimes. Individual soil survey projects may have locally developed guides and protocols based on local knowledge for assigning moisture regime classes to soils. Information about soil moisture regimes for an area can be found in previously published soil survey reports.

The map below shows the general pattern of soil moisture regimes across the United States. The classes shown include *ad hoc* moisture intergrade terms, such as “Typic Ustic” and “Ustic Aridic,” which are used in the subgroup category of Soil Taxonomy. The intergrade classes are not needed for this guide. For use of these keys, only the second term is needed. For example, “Ustic Aridic” will be considered as simply “Aridic.” This map can be used as a general guide for assigning a moisture regime class, but it is not definitive for any specific location.



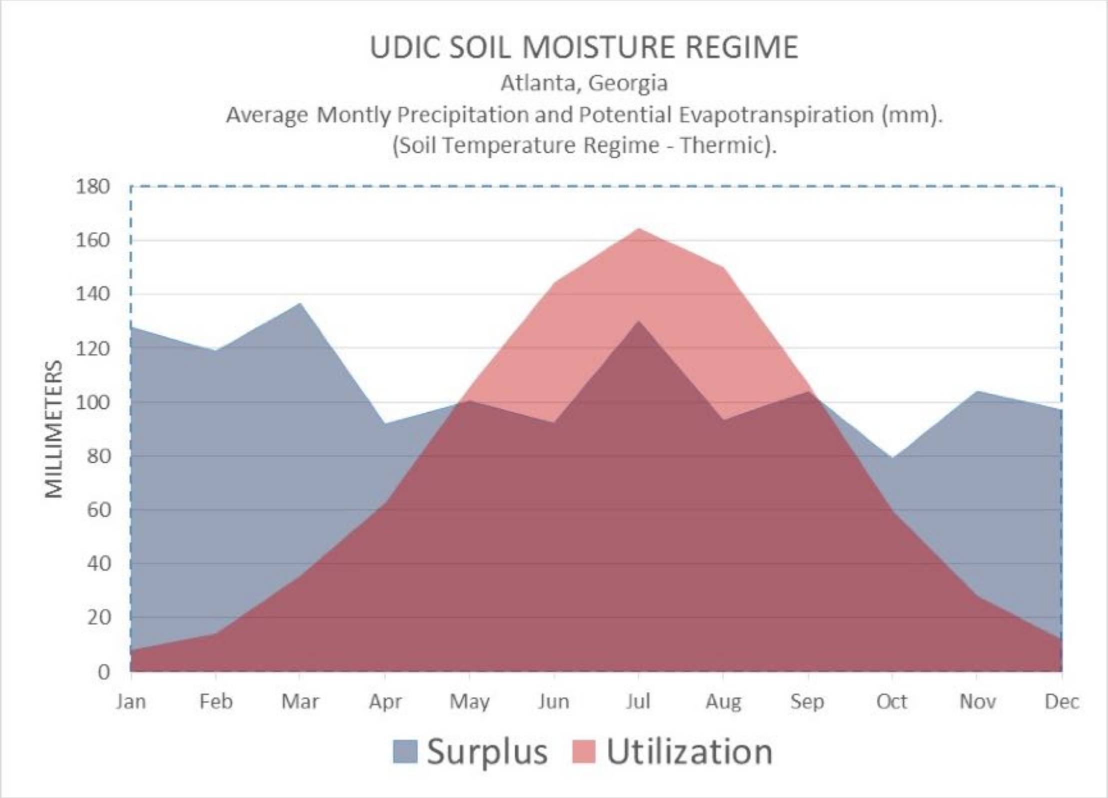
Back to discussion of Soil Moisture Regimes

The figures that follow were created with the Java Newhall Simulation Model. Each figure illustrates the basic environmental conditions embodied by a given soil moisture regime. The figures are based on data for the average monthly precipitation and evapotranspiration in the period 1971 to 2000 for the specified location. The soil moisture control section is assumed to be the zone between depths of 25 and 75 cm. Areas with the same soil moisture regime have similar patterns for the timing and intensity of the specific moisture inputs (precipitation) and outputs (evapotranspiration). It is important to remember that the soil moisture regime is defined by the timing and duration of moist or dry conditions within the moisture control section (a property of the soil) and not by specific amounts of precipitation and evapotranspiration.



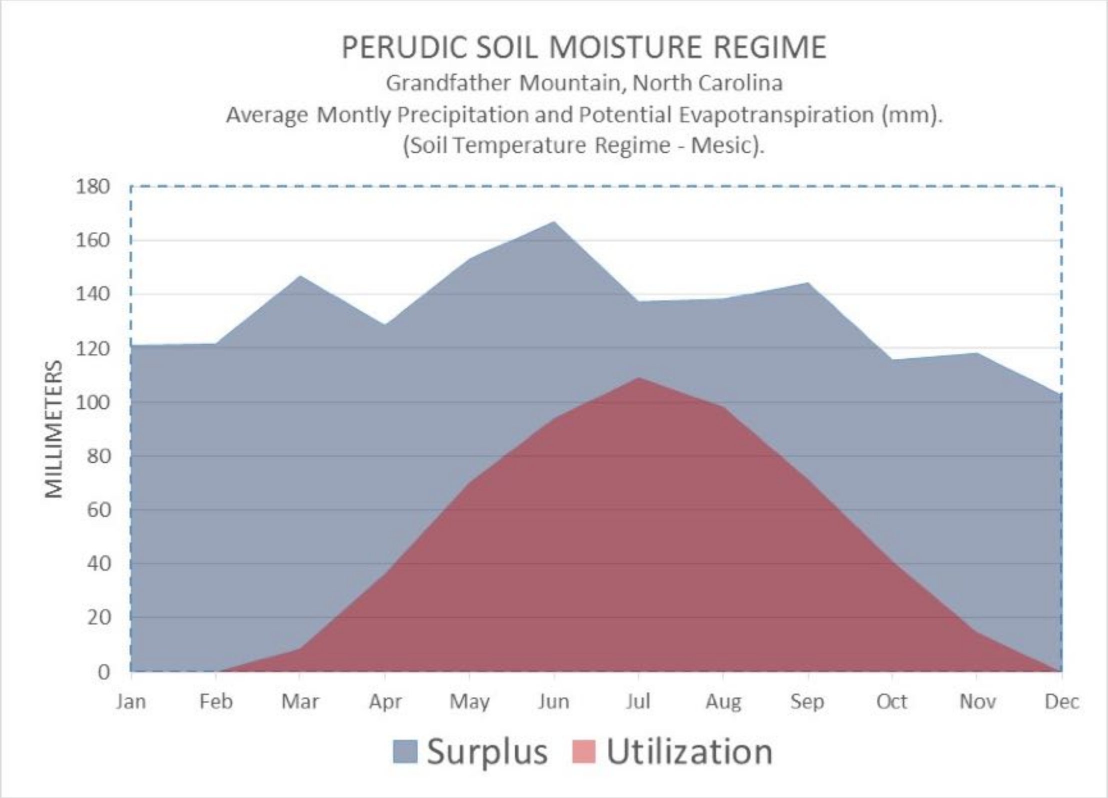
Average monthly precipitation and evapotranspiration for Winnemucca, Nevada. Except for the winter months, evapotranspiration greatly exceeds precipitation. Based on the Newhall model, the soil moisture control section is estimated to be dry throughout for 187 days and part moist and part dry for the rest of the year.

Return to discussion of the aridic soil moisture regime.



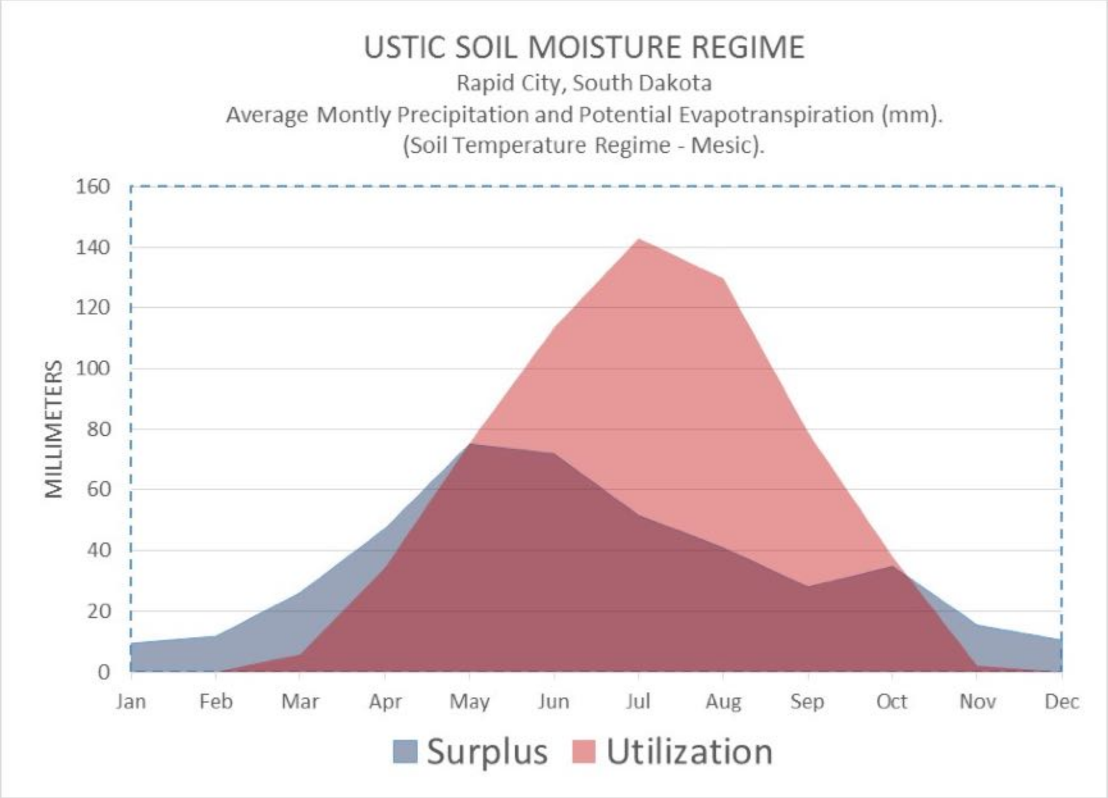
Average monthly precipitation and evapotranspiration for Atlanta, Georgia. Precipitation generally occurs throughout the year. Evapotranspiration exceeds precipitation during late spring and summer. Based on the Newhall model, the soil moisture control section is estimated to be moist throughout for 354 days and part moist and part dry for the rest of the year.

Return to discussion of the udic soil moisture regime.



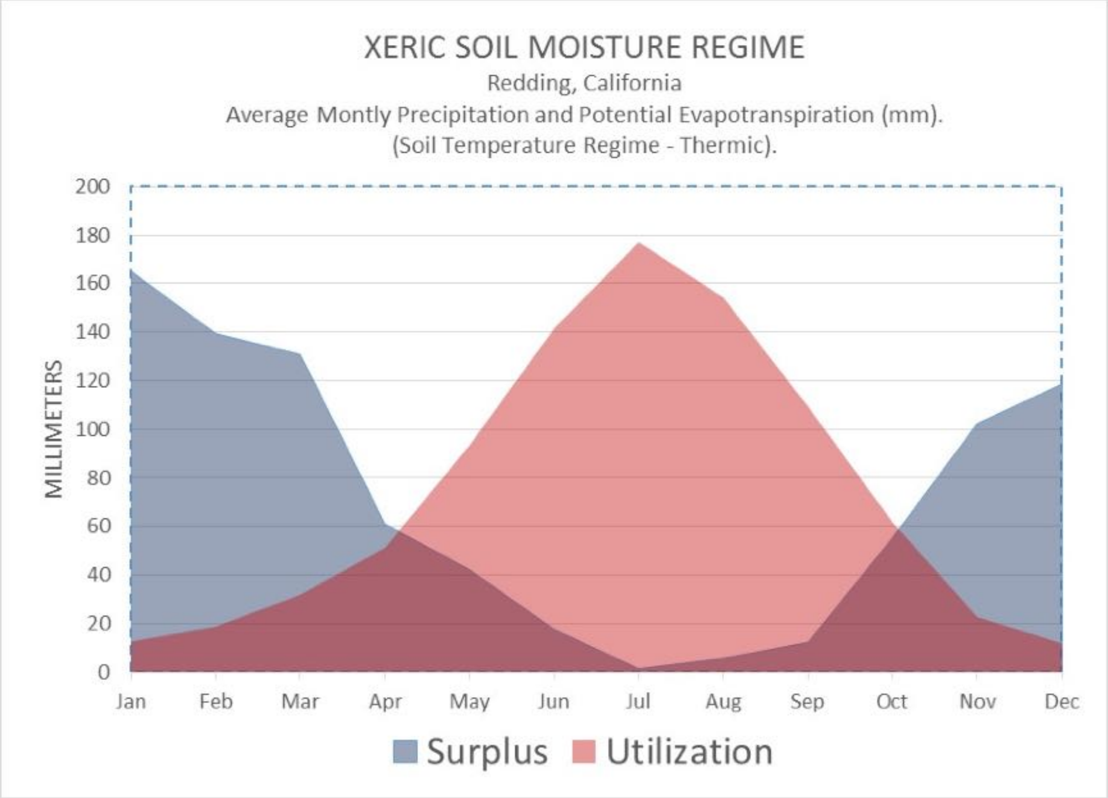
Average monthly precipitation and evapotranspiration at a high-elevation site on Grandfather Mountain, North Carolina. Precipitation occurs throughout the year and exceeds evapotranspiration in all months in most years. Based on the Newhall model, the soil moisture control section is estimated to be continually moist year-round.

Return to discussion of the perudic soil moisture regime.



Average monthly precipitation and evapotranspiration for Rapid City, South Dakota. Precipitation occurs mostly during spring and summer and is limited during the winter months. Evapotranspiration significantly exceeds precipitation during the late spring and summer. Based on the Newhall model, the soil moisture control section is estimated to be moist throughout for 95 days, dry throughout for 133 days, and part moist and part dry for the rest of the year.

Return to discussion of the ustic soil moisture regime.



Average monthly precipitation and evapotranspiration for Redding, California. Precipitation occurs mostly during winter. Evapotranspiration significantly exceeds precipitation during summer. Based on the Newhall model, the soil moisture control section is estimated to be moist throughout for 220 days, dry throughout for 90 days, and part moist and part dry for the rest of the year.

Return to discussion of the xeric soil moisture regime.

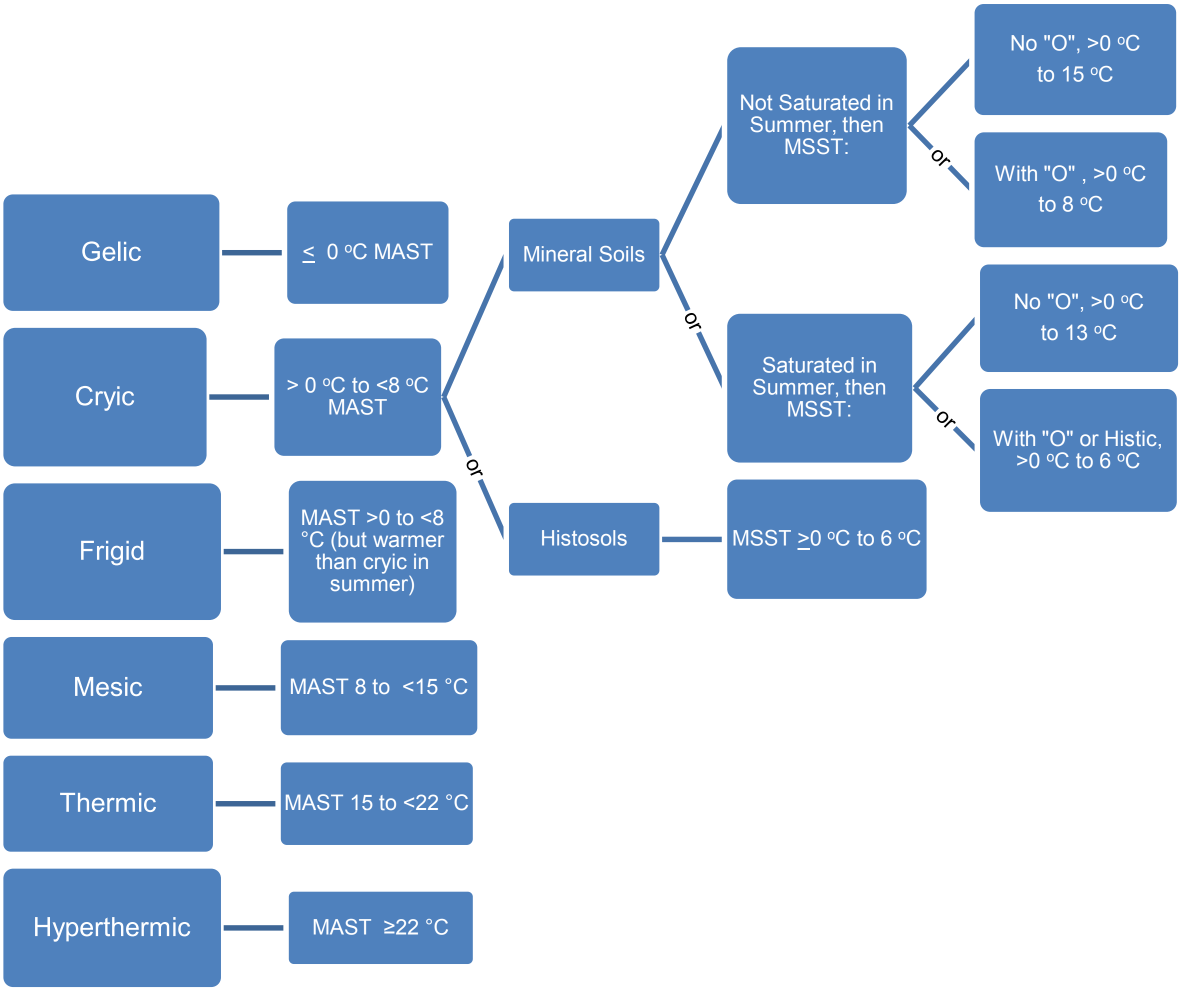
Soil Temperature Regimes

Some of the suborders and great groups are defined with either the *gelic* or *cryic* soil temperature regime. Although Soil Taxonomy recognizes a total of 10 temperature regimes, only these two coldest regimes are used at the suborder and great group levels. The other regimes, which are used in defining the lower classes and some diagnostic horizons and are mentioned in some of the descriptions of taxa, are included here for reference. The soil temperature regimes are defined by mean annual soil temperature (MAST) at a depth of 50 cm from the soil surface (or at a densic, lithic, or paralithic contact if it is shallower than 50 cm). Mean summer soil temperature (MSST) at the same depth is also used in the cryic regime definition. "Iso" temperature regimes (e.g., isothermic, isomesic, etc.) have a difference of < 6 °C between mean summer and mean winter temperatures. The "iso" regimes are not presented here since they are not used in this guide. Specific criteria for each temperature regime are given in chapter 3 of the current "Keys to Soil Taxonomy." Soil temperature is discussed in detail in "Soil Taxonomy," 2nd edition (chapter 3). A good discussion of soil temperature measurement and interpretation of data is provided in Soil Survey Investigations Report No. 48 ("TheTemperature Regime for Selected Soils in the United States," USDA-NRCS, 2002).

The criteria (modified from the "Field Book for Describing and Sampling Soils," version 3.0) for each temperature regime are summarized below in text and flow charts:

Gelic—Soil is ≤0 °C.
Cryic—Soil is > 0 to < 8 °C but has no permafrost and summer temperatures are also cold (see diagram below regarding summer temperatures in the cryic regime).
Frigid—Soil is > 0 to < 8 °C (but warmer than cryic soils in summer).
Mesic—Soil is 8 to < 15 °C.
Thermic—Soil is 15 to < 22 °C.
Hyperthermic—Soil is ≥ 22 °C.

Soil temperature is affected by inherent soil properties that determine the capacity of the soil to absorb and transmit heat, such as moisture content, porosity, and mineralogy. It is also greatly affected by site characteristics, such as drainage, vegetative cover, seasonal snow cover, slope steepness and aspect, elevation, and latitude.



Flow chart for determining soil temperature regime.

Back to discussion of Soil Temperature Regimes

Methods for determining soil temperature regime include the following:

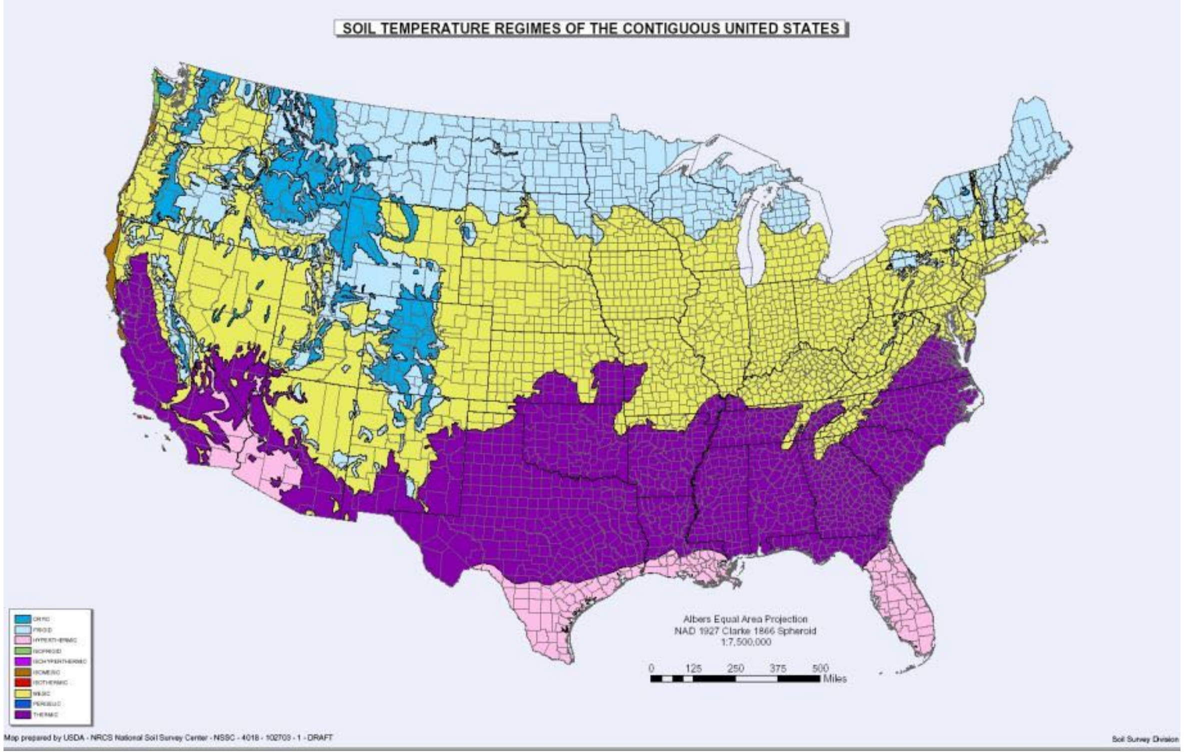
1) Soil temperature is measured in the field with manual thermometers, thermocouples, or digital sensors. It is relatively easy to install automated sensors for recording temperature over time, and this is frequently done to obtain data used in classifying soils. This is not practical, however, for obtaining immediate results. As few as four temperature measurements equally spaced throughout the year (e.g., January 1, April 1, July 1, and October 1) give very close approximations of mean annual soil temperature.

2) The mean annual soil temperature is estimated from available records of air temperature. For the continental United States, adding about 1 or 2 °C to the mean annual air temperature will approximate MAST at a

depth of 50 cm, although the actual relationship varies from location to location and the difference can be greater. The Java Newhall Simulation Model can estimate soil temperature regime based on air temperature records.

3) Where previous soil survey data collection and field experience are well documented, soil temperature regimes are inferred from geographic location (including general geographic location, elevation, aspect, and topographic relationships) as well as from knowledge of relationships between natural vegetation and temperature regimes. Individual soil survey projects may have locally developed guides and protocols based on local knowledge for assigning temperature regime classes to soils. Information about soil temperature regimes for an area can be found in previously published soil survey reports.

The map below shows the general pattern of soil temperature regimes across the continental United States. The gelic soil temperature regime has not been documented in soils of the continental U.S. but occurs in the soils of Alaska. This map can be used as a general guide for assigning a soil temperature regime, but it is not definitive for any specific location.



Back to discussion of Soil Temperature Regimes

Important Sources of Information Supporting the Use of the Illustrated Guide to Soil Taxonomy

This guide includes many terms that have specific technical definitions. While many items are described and defined in Part 2—Diagnostic Horizons and Features, other terms are not. It is assumed that the user is either familiar with the definitions or knows which source documents can provide the definitions. Specifically, it is assumed that the user is familiar with the commonly used sources of soil survey standards, including:

> Keys to Soil Taxonomy (Soil Survey Staff. 2014. Keys to soil taxonomy, 12th edition. U.S. Department of Agriculture, Natural Resources Conservation Service.)
>
> Guide to Pronouncing Taxonomic Terms (Soil Survey Staff. 2015. Guide to pronouncing terms used in soil taxonomy and soil survey. U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska.)
>
> Soil Survey Manual (Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18.)
>
> Soil Taxonomy (Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service. U.S. Department of Agriculture Handbook 436.)
>
> Field Book for Describing and Sampling Soils (P.J. Schoeneberger, D.A. Wysocki, E.C. Benham, and Soil Survey Staff. 2012. Field book for describing and sampling soils, version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska.)

Definitions of many of the terms used can also be found in the Soil Science Society of America’s online, searchable Glossary of Soil Science Terms.

Abbreviations and Acronyms

$CaCl_2$	calcium chloride
$CaCO_3$	calcium carbonate
CEC	cation-exchange capacity
$cmol^+$	centimoles of charge
COLE	coefficient of linear extensibility
dS/m	decisemens per meter
EC_e	electrical conductivity of the saturation extract
ECEC	effective cation-exchange capacity
ESP	exchangeable sodium percentage

HCl	hydrochloric acid
K_{sat}	saturated hydraulic conductivity
KOH	potassium hydroxide
MAST	mean annual soil temperature
MCS	moisture control section
MSST	mean summer soil temperature
NaOH	sodium hydroxide
NH_4OAc	ammonium acetate
NRCS	Natural Resources Conservation Service
O.C.	organic carbon
ODOE	optical density of oxalate extract
P_2O_5	phosphorus pentoxide (phosphorous oxide)
pH	power of hydrogen (hydrogen ion activity)
SAR	sodium absorption ratio
USDA	United States Department of Agriculture

Part 2—Horizon Nomenclature Used for Describing Soil Profiles

Background Information

The purpose of horizon nomenclature is to provide a standard short-hand method to label soil horizons in profile descriptions. Nomenclature allows soil scientists to convey information to the reader about the presence of key properties and genetic processes that have produced the morphology observed in the soil profile. The nomenclature tells a story expressing the genetic development of the soil. Click here to see a video about describing soil horizons in the field.

The nomenclature for designating kinds of horizons consists of five kinds of characters. For any given horizon, however, only those characters needed to effectively label it (typically just two to four) are used.

1. **Master horizon symbol**. Capital letters, such as A, E, B, and C, are used to designate the kind of master horizon. Table 1 lists the nine master horizon designations and provides a general description of each.
2. **Suffix symbols**. Lowercase letters following the master horizon symbol are used to further describe one or more important characteristics of the horizon. Examples include Ap, Bt, and Bk. Tables 2A and 2B list 34 suffix symbols that can be used and provides a general description of each one. Table 2A lists those used to indicate physical characteristics, and Table 2B lists those used to indicate chemical or mineralogical characteristics.
3. **Vertical subdivisions**. Numbers can be added at the end of the horizon designation to subdivide a horizon having the same combination of master and suffix letters. Vertical subdivisions are generally used to split master horizons based upon minor variations, such as slight changes in color and structure or differences in the amount or size of features.
4. **Lithologic discontinuities**. A number is placed before the master horizon symbol to designate a significant change, such as particle-size distribution or mineralogy, in the lithology of mineral soils.
5. **Special symbols**
    a. Horizons that formed in human-transported materials are indicated by a caret symbol (^) preceding the master horizon symbol.
    b. When a sequence of horizons is repeated in different parts of a soil profile (sometimes called a bisequal soil) the prime symbol (´) is used after the master horizon letter in the second sequence.

Conventions for the Use of Horizon Nomenclature

Some basic rules are listed below. See the “Keys to Soil Taxonomy” for more detailed information.

1. Vertical subdivisions of horizons with the same master and suffix letter symbols are indicated by a number at the end of the horizon

designation. An example sequence for a soil profile with subdivisions of the A and Bt horizons is: A1-A2-E-Bt1-Bt2–C.

2. Lithologic discontinuities in mineral soils are indicated by a number preceding the master horizon letter. An example sequence for a profile of a soil that formed in loess over glacial till underlain by bedrock is: A-E-Bt1-Bt2-2BC-2C-3R. In this sequence, the A, E, and Bt horizons developed in loess while the BC and C horizons are glacial till (and therefore preceded by the number 2). Since the bedrock (R) is not the source of parent material for the soil above, it is preceded with the number 3, which indicates another discontinuity. Note that the number 1 is understood and therefore not used.

3. Horizons that are composed of human-transported material are indicated by using a caret symbol (^) as a prefix to the master horizon letter. An example sequence for a profile of a soil that formed in human-transported organic soil material over a naturally occurring mineral soil is: ^Oau1-^Oau2-A-B-C.

4. In cases where two or more horizons having identical number prefixes and master and suffix letters are separated by a different kind of horizon, the prime symbol (´) is used after the master horizon letter of the lower sequence. For example, the profile of a soil having two E horizons separated by a Bt horizon is designated as: A-E-Bt-E´-Btx-C. Only horizons with identical number prefixes and master and suffix letters are designated with the prime symbol (thus no prime symbol is used for the sequence: A-E-Bt-2E-2Btx-2C). Number suffixes used at the end of the horizon designation to indicate vertical subdivisions of horizons are not considered when using the prime symbol. For example, the sequence A-E-Bt-E´-B´t1-B´t2-C shows the appropriate use the prime symbol.

5. Master horizon symbols may be combined in the following situations:

    a. *Transitional horizons*. In cases where a horizon is in a position of transition and is dominated by the properties of one master horizon type, but has subordinate properties of another master horizon type, two master horizon letters may be used. For example, an AB horizon has characteristics of both an overlying A horizon and an underlying B horizon but is more like an A than a B horizon (thus A comes first). Other examples include BA, EB, BE, BC, and CB.

    b. *Horizons with two distinct parts*. In cases where a horizon has distinct parts, each having recognizable characteristics of two different forms of master horizons, both master horizon symbols are used and separated by a virgule (/). The dominant part is listed first. Examples include A/B, B/A, E/B, and B/C.

c. *Horizons containing lamellae*. In cases where a horizon has lamellae, the two master horizon letters are combined by the word “and.” Examples include “E and Bt” and “Bt and E.”

Table 1.—Master Soil Horizons and the Nomenclature (Capital Letters) Used to Designate Them in Soil Profile Descriptions

Horizon Symbol	General Description
A	Surface mineral soil horizon, generally darkened by accumulating humus. May be buried by newer deposits or underlie an organic horizon.
B	Subsoil mineral horizon, generally characterized by accumulation, removal, or redistribution of constituents such as iron, aluminum, silica, clay, humus, calcium carbonate, calcium sulfate, or sesquioxides. May be at the surface in a truncated soil.
C	Relatively unaltered mineral soil layer underlying the pedogenically developed soil profile. Generally unconsolidated, but includes soft bedrock.
E	Subsurface mineral soil horizon characterized by a loss of iron, aluminum, clay, or organic matter. Generally has lighter color and coarser texture compared to horizon above.
L	Soil horizon composed of organically derived limnic material that was deposited in water by chemical precipitation or aquatic organisms or came from plants (as modified by organisms). Examples include coprogenous earth, diatomaceous earth, and marl.
M	Root-limiting, human-manufactured layer. Examples include a buried layer of continuous asphalt, landfill liner, and geotextile fabric.
O	Soil horizon composed dominantly of organic soil materials (but not limnic materials). Has relatively low bulk density compared to mineral soil. May be at the surface or buried.
R	Consolidated hard, continuous bedrock.
V	Mineral horizon 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. Characterized by the predominance of vesicular pores and having platy, prismatic, or columnar structure.
W	Layer of water within or under the soil (not at the surface). Examples include floating bogs and segregated ice layers.

Table 2A.—Subordinate Lowercase Suffixes Describing Physical Characteristics of the Soil

Suffix	General Description
a	Highly decomposed organic matter. Has < 17%, by volume, rubbed fiber. Used only with master horizon O.
b	Buried genetic horizon. Exhibits past soil-forming development.
c	Presence of cemented concretions or nodules.
d	Physically root-restrictive layer due to high bulk density. May have natural or human-induced compaction. Examples include dense basal till and plow pans.
e	Moderately decomposed organic matter. Has 17 to < 40%, by volume, rubbed fiber. Used only with master horizon O.
f	Permanently frozen layer that contains ice (permafrost).
ff	Dry permafrost. Permanently frozen layer, not cemented by ice.
i	Slightly decomposed organic matter. Has $\geq$ 40%, by volume, rubbed fiber. Used only with master horizon O.
jj	Evidence of cryoturbation in the active layer above permafrost. Examples include broken or irregular horizons boundaries, organic bodies within mineral horizons, and sorted rock fragments.
m	Root-restrictive, pedogenically cemented horizon. More than 90% of layer is cemented by agents such as calcium carbonate, iron, silica, gypsum, or other salts.
p	Disturbance of the surface layer, commonly by plowing, cattle trampling, vehicle traffic, or other mechanical means. Used with master horizon A.
r	Weathered or soft bedrock. Although cemented, it can be dug with hand tools, such as a spade or pick. Used with master horizon C.
ss	Presence of slickensides formed by shear movement in clayey soils as a result of shrinking and swelling.
t	Illuvial accumulation of clay as evidenced by the presence of clay films, clay bridges, or lamellae.
u	Presence of human-manufactured material (artifacts) such as bricks, metal, coal ash, fabric, rubber, plastic, glass, and garbage.
w	Weakly expressed color or structural development or minimal accumulation of pedogenic constituents. Used with master horizon B, but not with transitional horizons.
x	Genetically developed horizon that is firm, brittle, and physically root restrictive, at least in part.

Table 2B.—Subordinate Lowercase Suffixes Describing Chemical or Mineralogical Characteristics of the Soil

Suffix	General Description
co	Limnic layer composed primarily of coprogenous earth (fecal material from aquatic animals). Used only with master horizon L.
di	Limnic layer composed primarily of diatomaceous earth (sedimentary siliceous diatom remains). Used only with master horizon L.
g	Strong gleying (iron reduction and loss due to saturation and anaerobic conditions). Chroma is 2 or less.
h	Illuvial accumulation of amorphous, dispersible, organic matter and aluminum-dominated sesquioxides coating sand and silt particles and sometimes filling pores. Used with master horizon B.*
j	Accumulation of jarosite (iron hydroxy sulfate mineral with yellow hue produced in acid-sulfate soils).
k	Accumulation of visible pedogenic calcium carbonate (< 50%, by volume). Forms include filaments, soft masses, nodules, pendants, and finely disseminated carbonates.
kk	Engulfment of the horizon by pedogenic calcium carbonate (≥ 50%, by volume). Carbonates coat particles and fill pores, effectively plugging the soil fabric.
ma	Limnic layer composed primarily of marl (soft, muddy deposit of sedimentary calcium carbonate and clay). Reacts with dilute HCl. Used only with master horizon L.
n	Accumulation of exchangeable sodium.
o	Residual accumulation of sesquioxides (iron- and aluminum-oxides).
q	Accumulation of secondary silica as concretions, durinodes, opal, etc.
s	Illuvial accumulation of amorphous, dispersible sesquioxides (iron- and aluminum-oxides) and organic matter. Used with master horizon B.*
se	Presence of sulfides in mineral or organic layers. Often associated with sulfurous odor (rotten-egg smell). Typically dark in color (value ≤ 4 and chroma ≤ 2).
v	Presence of plinthite (firm, iron-rich, humus-poor, red concentration in association with clay, quartz, and other minerals). Irreversibly hardens with repeated wet/dry cycles (as in a road cut).
y	Accumulation of gypsum (or rarely, anhydrite). Because amounts are sufficiently low (< 50%, by volume) the gypsum does not disrupt or obscure other features of the horizon.
yy	Dominance of the horizon by accumulated gypsum (or rarely, anhydrite). Amounts are sufficiently high (> 50%, by volume) for the growth of gypsum crystals to disrupt or obscure other features of the horizon. Color is typically white (value ≥ 7 and chroma ≤ 2).
z	Accumulation of salts more soluble than gypsum, such as sodium chloride.

* Suffixes h and s are combined, as in Bhs, where the sesquioxide component is significant but the color has both moist value and chroma of 3 or less.

Part 3—Diagnostic Horizons and Characteristics

Introduction

The taxonomic classes defined in Soil Taxonomy group soils that have similar properties and that formed as a result of similar pedogenic processes. Rather than define classes based directly on theories of soil genesis, however, the classes are based largely on the presence of diagnostic horizons and characteristics. These diagnostic horizons and characteristics reflect the important pedogenic processes (i.e., additions, removals, transfers, and transformations) that are either occurring now, or have occurred in the past, to produce the kinds of soil profiles we see today. Some of the criteria used to define the diagnostic horizons and characteristics can be observed directly in the field (color, texture, thickness, etc.). Other properties can only be determined in the laboratory (cation-exchange capacity, percent gypsum, organic carbon content, etc.).

The following descriptions are divided into two sections. In the first section, the eight diagnostic surface horizons (epipedons) are presented. In the second section, 49 diagnostic subsurface horizons and characteristics needed to classify a soil to the great group level are discussed. There are more diagnostic characteristics, not discussed in this guide, that are used to define categories below the great group level. For information on these, see the 12th edition of the “Keys to Soil Taxonomy.” In addition, six soil moisture regimes and six soil temperature regimes are briefly described because they are used either in some of the criteria for taxonomic classes or in criteria for some of the diagnostic horizons.

For each diagnostic horizon or characteristic presented, the following is provided:

- **Heading.** A brief descriptive phrase is given for the item.
- **Concept and background information.** A brief narrative describes the concept of the item and basic information about it.
- **Generalized characteristics.** The criteria given in the “Keys to Soil Taxonomy,” 12th edition, are presented in a somewhat simplified and illustrated version. Information has been reworded, and, in a few cases, the critera have been reorganized. Some of the more complex details have been omitted. Generally, a note (italicized text that follows) alerts the reader if there are exceptions to the presented information or if additional information is available in the full version of the keys.
- **Common horizon nomenclature.** The master horizon and/or subordinate symbols that are commonly used in soil descriptions to indicate a particular diagnostic horizon or characteristic are identified.
- **Photos** (for most of the diagnostic horizons and characteristics)

It is important to note that, unlike the keys to the orders, suborders, and great groups (given in part 4 of this guide), the information presented in this section is NOT a key (i.e., the user does not start at the beginning and stop when the criteria are met). To become fully competent, a soil scientist needs to be familiar with the basic concepts and criteria of all the diagnostic horizons and characteristics (or at least all of those found in the local geographic area). Some of the diagnostic horizons are mutually exclusive, but not all. Two examples follow:

- The upper part of an argillic horizon that has significant accumulations of organic carbon could also qualify as part of a mollic or umbric epipedon, depending on base saturation.
- A layer with significant accumulations of both gypsum and calcium carbonate may qualify as both a calcic and gypsic horizon.

Epipedons

Diagnostic Subsurface Horizons and Characteristics (including temperature and moisture regimes)

Epipedons

The epipedon (Gr. *epi*, over, upon, and *pedon*, soil) is a horizon that forms at or near the surface and in which most of the rock structure has been destroyed. It is darkened by organic matter or shows evidence of eluviation, or both. Rock structure includes fine stratification (less than 5 mm) in unconsolidated sediments (eolian, alluvial, lacustrine, or marine) as well as saprolite derived from consolidated rocks in which the unweathered minerals and pseudomorphs of weathered minerals retain their relative positions to each other. *An epipedon is not the same as an A horizon. It may include part or all of an illuvial B horizon if the darkening by organic matter extends from the soil surface into or through the B horizon.*

Soil Taxonomy recognizes eight epipedons. The most common in the United States are the ochric, mollic, and umbric epipedons. In general, they are distinguished based on organic matter accumulation, color, thickness, and degree of base saturation. Two epipedons form in organic soil materials—histic and folistic epipedons. The more common histic forms on wet soils, while the less common folistic epipedon forms on more or less well drained soils. Provision is made to allow mineral versions of the folistic and histic epipedons if they are mixed by plowing. The melanic epipedon is unique to some soils with andic soil properties. Two epipedons are the result of human activity – the anthropic and plaggen epipedons. These are rare in the United States but are found in some local areas.

Brief Descriptions of the Epipedons

(Click on the links for more detailed information)

Anthropic—A thick horizon that formed in human-altered or human-transported material

Folistic—A more or less freely drained horizon that formed in organic materials

Histic—A saturated horizon that formed in organic materials

Melanic—A thick, dark-colored, humus-rich horizon in which organic carbon is associated with poorly crystalline, short-range-order minerals or aluminum-humus complexes

Mollic—A thick, dark-colored, humus-rich horizon with high base status

Ochric—A more or less minimally developed surface horizon, typically thin or light colored, that does not meet the criteria for any other epipedon

Plaggen—A human-developed surface layer resulting from long-term manuring and spading

Umbric—A thick, dark-colored, humus-rich horizon with low base status

Soil profile (of a Torriorthent in the United Arab Emirates) showing rock structure as fine to coarse stratifications throughout. The upper 60 cm is recent eolian sand. The lower part consists of old alluvial deposits interspersed with eolian strata. Scale is in cm. (Photo courtesy of Dr. Craig Ditzler)

Back to introduction of Epipedons

Anthropic Epipedon

A thick horizon that formed in human-altered or human-transported material

Concept and Background Information

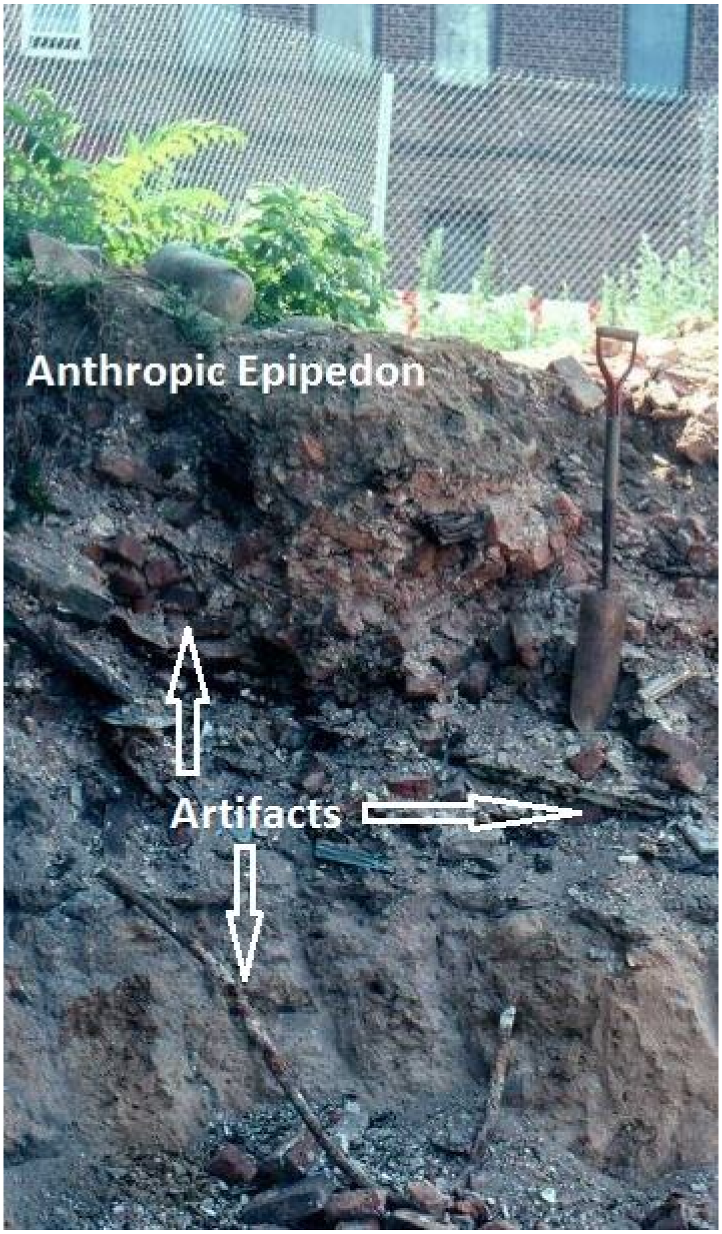
The anthropic epipedon is a thick horizon that formed in human-altered or human-transported material. The key feature is that it formed as the result of intentional human alteration (but not simply by the common agricultural practices of plowing and amending the soil with fertilizers). Its landscape setting (such as a raised surface due to filling) and/or presence of human artifacts are key characteristics.

Generalized Characteristics

1) When dry, horizon has structural units < 30 cm in size.
2) The original rock structure, including fine stratification, has been mostly obliterated.
3) Horizon consists of human-altered or human-transported material.
4) Soil is on an anthropogenic landform, contains artifacts or kitchen-middens, or has been compacted to impede drainage (as in paddy cultivation).
5) Minimum thickness is 25 cm.
6) When moist, horizon is not fluid.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon A, which may be in combination with a preceding caret symbol (^) and with suffix p or u. Examples include: ^Ap, ^Au, and Ap.



This soil in New York City formed in human-transported material with human artifacts in the profile, such as brick, glass, and metal. The surface layer is an anthropic epipedon.

Back to Anthropic Epipedon

Folistic Epipedon

An organic surface horizon that is freely drained

Concept and Background Information

The folistic epipedon is a layer that is more or less freely drained and that has sufficiently high amounts of organic carbon (O.C. ≥ 20%, by weight) to be considered organic soil material. Typically, it is at (or near) the surface and is at least 15 cm thick.

Included within the concept of the folistic epipedon are some layers which have been plowed. As a consequence of mixing with mineral soil material, and/or loss of organic carbon due to oxidation, these layers now have slightly lower amounts of organic carbon (8 to 16%, by weight, depending on clay content) and no longer qualify as organic soil material. This form of the folistic epipedon must be ≥ 25 cm thick.

The folistic epipedon is used only with mineral soils (i.e., it is not recognized in Histosols).

Generalized Characteristics

Horizon is:
1) Freely drained, *and*
2) High in organic material (generally > ~ 15% O.C., by weight, depending on clay content), *and*
3) At least 15 cm thick.

Note: The layer is saturated < 30 days cumulative annually. Minimum thickness and organic carbon requirements vary depending on the kind of organic matter (affecting bulk density) and whether or not the site is plowed. For the plowed condition, the minimum required O.C. weight % is 8 + (clay% / 7.5). If the layer is ≥ 60% clay, O.C must be ≥ 16%, by weight.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon O (and less commonly A), which may be in combination with suffix p, e, or i. Examples include: Oi, Oe, and Ap.

Histic Epipedon

An organic surface horizon that is periodically saturated

Concept and Background Information

The histic epipedon is a horizon that is periodically saturated with water and that has sufficiently high amounts of organic carbon (O.C. 12 to 18%, by weight, depending on clay content) to be considered organic soil material. Typically, it is at (or near) the surface and is peat or muck at least 20 cm thick.

Included within the concept of the histic epipedon are some layers which have been plowed. As a consequence of mixing with mineral soil material, and/or loss of organic carbon due to oxidation, these layers now have slightly lower amounts of organic carbon (8 to 16%, by weight, depending on clay content) and no longer qualify as organic soil material. This form of the histic epipedon must be $\geq$ 25 cm thick.

The histic epipedon is used only with mineral soils (i.e., it is not recognized in Histosols).

Generalized Characteristics

Horizon is:
1) Poorly drained (saturated periodically), *and*
2) High in organic material (generally > ~ 15% O.C., by weight, depending on clay content), *and*
3) At least 20 cm thick.

Note: The layer is saturated $\geq$ 30 days cumulative annually. Minimum thickness and organic carbon requirements vary depending on the kind of organic matter (affecting bulk density) and whether or not the site is plowed. For the undisturbed condition, the minimum required O.C. weight % is 12 + (clay% X 0.1). If the layer is $\geq$ 60% clay, O.C must be $\geq$ 18%, by weight. For the plowed condition, the minimum required O.C. weight % is 8 + (clay% / 7.5). If the layer is $\geq$ 60% clay, O.C must be $\geq$ 16%, by weight.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon O (and less commonly A), which may be in combination with suffix p, a, e, or i. Examples include: Oa, Oe, and Ap.

Soil profile (in Alaska) that has a histic epipedon extending to a depth of about 38 cm. The upper 20 cm is fibric soil material that has a high content of sphagnum. Scale is in cm. (Photo courtesy of Dr. David Weindorf)

Back to Histic Epipedon

Melanic Epipedon

A thick, very dark-colored, humus-rich horizon with andic properties

Concept and Background Information

The melanic epipedon is a thick (≥ 30 cm), very dark-colored (commonly black), humus-rich horizon with unique chemical and physical properties. It is typically at the soil surface, but may begin as much as 30 cm below the soil surface in places where it is covered by a younger layer, such as an ash fall or alluvial deposit. It is generally associated with soils that formed in materials of volcanic origin and has high concentrations of organic carbon (≥ 6%, by weight) derived mostly from the root residue of grasses and other similar vegetation. The humus is chemically associated with aluminum and poorly crystalline minerals, such as allophane, imogolite, and ferrihydrite (andic soil properties). As a result, the soil exhibits unique chemical and physical properties, including a high water-holding capacity, a relatively low bulk density, and an ability to bind with the important plant nutrient phosphorus so tightly that the nutrient is not available to plants.

Generalized Characteristics

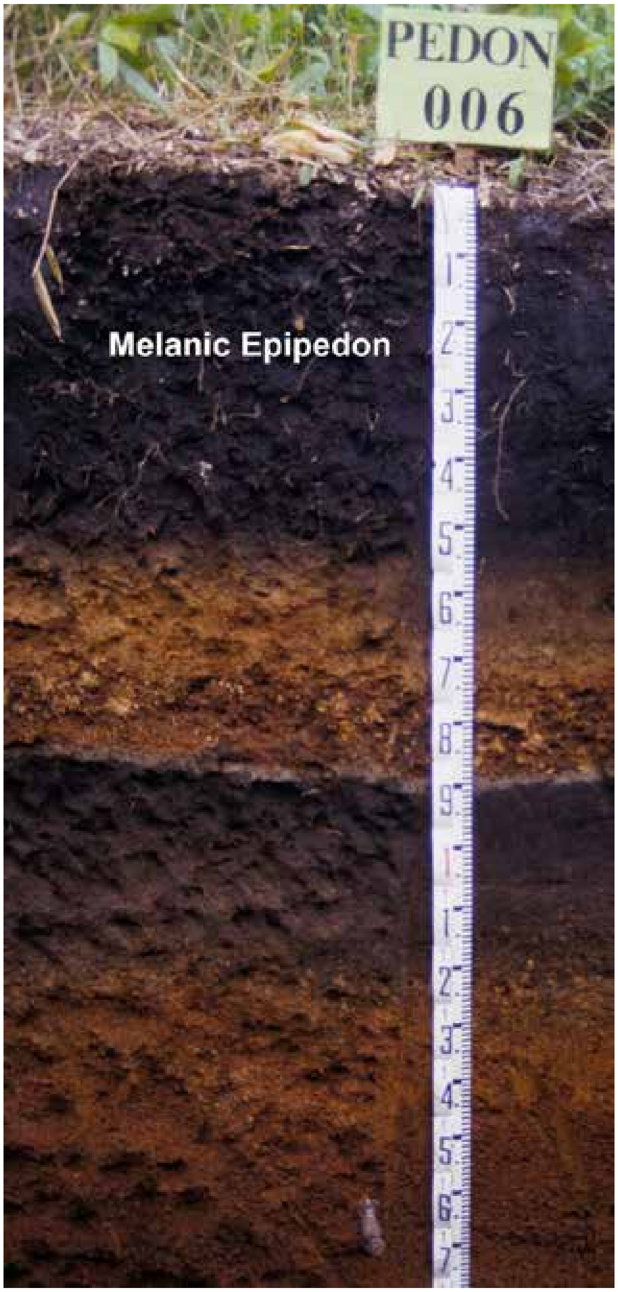
Horizon:

1) Begins at (or within 30 cm of) the surface and has a cumulative thickness of ≥ 30 cm.
2) Has color value (moist) ≤ 2.5 and chroma ≤ 2.
3) Has melanic index value of < 1.7.
4) Has an overall average of organic carbon ≥ 6%, by weight.
5) Meets the criteria for andic soil properties criteria throughout.

Note: The melanic index value of ≤ 1.70 indicates that fulvic acids make up more than about 40% of the combined total of humic and fulvic acids in the organic fraction of the soil, thus verifying the significant contribution of grass or grass-like plants. See 12th edition of the “Keys to Soil Taxonomy” for the criteria for andic soil properties.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon A, which may be in combination with suffix p, for example, A or Ap.



An Andisol in Japan that has a thick, dark melanic epipedon. A paleosol is below a depth of 90 cm. Scale is in cm.

Back to Melanic Epipedon

Mollic Epipedon

A thick, dark-colored, humus-rich horizon with high base status

Concept and Background Information

The mollic epipedon is a thick, friable, dark-colored (mostly very dark brown to black), humus-rich surface horizon with high base status. Because of the favorable base status, it has high native fertility and calcium, magnesium, and other important positively charged elements dominate the cation exchange sites. The properties of the mollic epipedon are, to a significant degree, the result of inputs of organic matter and nutrients from deep-rooted vegetation that is highly productive of below-ground biomass, such as that associated with grassland or savannah ecosystems. The organic matter and nutrients are further cycled by earthworms and other soil organisms, resulting in a thick, fertile, humus-rich surface horizon.

Generalized Characteristics

1) When dry, horizon is not both massive and hard.
2) The original rock structure, including fine stratification, is mostly obliterated.
3) Moist value and chroma are $\leq$ 3 and dry value is $\leq$ 5. (Lighter colors are allowed if calcium carbonate [$CaCO_3$] is $\geq$ 15%).
4) Minimum thickness is 25 cm for most soils. Exceptions include:
    a. 10 cm if the epipedon rests directly on bedrock (and is not sandy) or rests on a densic contact, a petrocalcic horizon, or a duripan.
    b. 18-25 cm if the epipedon is not sandy and it is at least:
        i. 1/3 the depth to carbonates, or to a calcic horizon, petrocalcic horizon, duripan, or fragipan, or
        ii. 1/3 the solum thickness (as indicated by the base of an argillic, cambic, natric, oxic, or spodic horizon).
5) Base saturation is $\geq$ 50% throughout the layer (by NH_4OAc sum of bases).
6) Organic carbon is $\geq$ 0.6% (by weight), about 1% organic matter content. (Exceptions include a higher required O.C. for soils with high calcium carbonate equivalent or for soils that formed in naturally dark-colored parent materials).
7) Horizon is moist in some part for $\geq$ 90 total days during the growing season (not from irrigation).
8) When moist, horizon is not fluid.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon A, which may be in combination with suffix p. In addition, the mollic epipedon may extend into the subsoil and include horizons with master symbol AB, BA, or B and various suffixes, including k, n, t, ss, and w. Examples include: A, Ap, AB, and Bt.

A mollic epipedon with granular structure (soil profile in Romania). (Photo courtesy of Dr. David Weindorf)

Back to Mollic Epipedon

Ochric Epipedon

A minimally developed surface horizon that is typically thin and/or light-colored

Concept and Background Information

The ochric epipedon typically includes surface layers that are only slightly or moderately darkened by organic matter (mostly light yellowish brown to brown) as well as any lighter-colored eluvial horizons below (A and E horizon sequence), extending to the first underlying diagnostic subsoil horizon. However, rather than providing a definition based on the properties of the horizon, Soil Taxonomy simply defines as ochric epipedons those surface horizons that fail to meet the definitions for any of the other seven epipedons. For example, a horizon may meet all the criteria for a mollic epipedon except that it is too thin or too light in color. In other cases, a horizon may be composed of organic soil material but be too thin to qualify as either a histic or folistic epipedon. As a consequence, the ochric epipedon can closely resemble in form any of the other epipedons but fails to have one or more of their characteristics, possibly by just a small amount.

Generalized Characteristics

Soil Taxonomy does not provide a list of required characteristics for the ochric epipedon. This is due to the nature of the ochric as a “catch-all” epipedon for those horizons that fail to meet the requirements given for any of the other seven epipedons. It must be remembered, however, that to qualify as an ochric epipedon, the horizon in question must:

1) Meet the definition for an epipedon:
   a. Horizon formed at or near the surface.
   b. Most rock structure, including fine stratification, has been destroyed.
   c. Horizon has been darkened by organic matter and/or shows evidence of eluviation.
2) Fail to have one or more of the required characteristics of all other epipedons.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizons A, E, and O, which may be in combination with suffix a, e, i, or p. Examples include: A, Ap, E, and Oi.

Profile of an Andisol with a thin ochric epipedon that has been darkened by organic matter. Scale is in cm.

Back to Ochric Epipedon

Plaggen Epipedon

A thick, dark-colored, human-made surface layer produced by long-term manuring and spading

Concept and Background Information

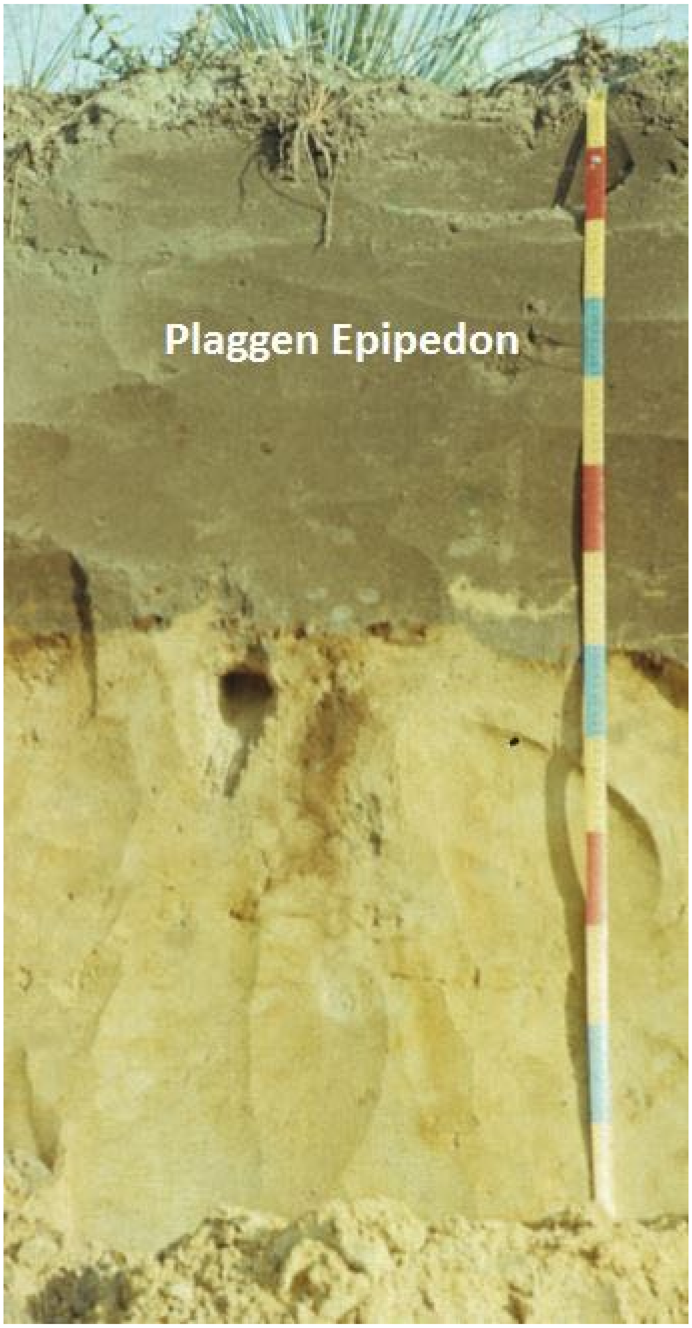
The plaggen epipedon is a thick, dark-colored (typically black to dark grayish brown) human-made mineral surface layer produced by long-term manuring and spading. It typically contains a few artifacts, such as bits of brick and pottery, throughout. It was originally recognized in Europe and has generally not been recognized in the United States. In medieval times, sod or other materials commonly were used for bedding livestock and the manure was spread on nearby cultivated fields. The mineral materials brought in by this kind of manuring eventually produced an appreciably thickened Ap horizon (as much as 1 m or more thick). In northwestern Europe, this custom was associated with the poorly fertile, sandy Spodosols. The practice more or less ceased at the turn of the 19th century, when synthetic fertilizers became readily available. An area of soil with a plaggen epipedon tends to have straight-sided rectangular borders that are higher than the adjacent soils by as much as or more than the thickness of the plaggen epipedon.

Generalized Characteristics

1) Horizon occurs in soils on elevated landforms which contain artifacts (not including agricultural amendments) or spade marks.
2) Color value is ≤ 4 moist (≤ 5 dry), and chroma is ≤ 2.
3) Organic carbon content is ≥ 0.6% (by weight), about 1% or more organic matter.
4) Horizon has ≥ 50 cm of human-transported material.
5) Horizon is moist in some part for ≥ 90 total days during the growing season (not from irrigation).

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon A, which may be preceded by the caret symbol (^) and be in combination with suffixes p and/or u. Examples include: Ap and ^Apu.



Profile of a soil from Holland with a plaggen epipedon that formed from long-term manuring. Scale colors are in 10-cm increments.

Back to Plaggen Epipedon

Umbric Epipedon

A thick, dark-colored, humus-rich horizon with low base status

Concept and Background Information

The umbric epipedon is a thick, dark-colored (mostly very dark brown to black), humus-rich surface horizon with low base status. The base status is relatively low (< 50% in some part or the entire horizon) because relatively high proportions of aluminum and possibly hydrogen (rather than calcium, magnesium, sodium, and potassium) occupy a significant number of the exchange sites. This is generally characteristic of acid soils with low to moderate native fertility levels. The umbric epipedon is thought to be formed mainly by the decomposition of organic residues. The decomposed organic residues are partly roots and partly surface organic residues that have been taken underground by soil fauna. Accumulation and turnover of the organic matter probably are slower in the umbric epipedon than in the mollic epipedon. The aluminum ions may be somewhat toxic to some kinds of soil micro-organisms.

Generalized Characteristics

1) When dry, horizon is not both massive and hard.
2) The original rock structure, including fine stratification, is mostly obliterated.
3) Moist value and chroma are $\leq$ 3, and dry value is $\leq$ 5.
4) Minimum thickness is 25 cm (for most soils). Exceptions include:
   a. 10 cm if the epipedon rests directly on bedrock (and is not sandy) or rests on a densic contact, a petrocalcic horizon, or a duripan.
   b. 18-25 cm if the epipedon is not sandy and it is at least:
      i. 1/3 the depth to carbonates or to a calcic horizon, petrocalcic horizon, duripan, or fragipan, or
      1. 1/3 the depth of solum thickness (as indicated by the base of an argillic, cambic, natric, oxic, or spodic horizon).
5) Base saturation is < 50% in at least part of the horizon (by NH_4OAc sum of bases).
6) Organic carbon is $\geq$ 0.6% (by weight), about 1% organic matter content. (Exceptions exist for soils that formed in naturally dark-colored parent materials).
7) Horizon is moist in some part for $\geq$ 90 total days during the growing season (not from irrigation).
8) When moist, horizon is not fluid.
9) Horizon has no human artifacts (as required for the plaggen epipedon).

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon A, which may be in combination with suffix p. In addition, the umbric epipedon may extend into the subsoil and include horizons with master symbol AB, BA, or B and various suffixes, including h, s, t, and w. Examples include: A, Ap, AB, and Bt.

Profile of a soil in Japan with a thick umbric epipedon that was darkened by organic matter. Scale is in cm.

Back to Umbric Epipedon

Diagnostic Subsurface Horizons and Characteristics (including moisture and temperature regimes)

(Click the links for more detailed information.)

Abrupt Textural Change—A considerable increase in clay content over a short vertical distance

Agric Horizon—Subsoil horizon with accumulation of silt, clay, and humus

Albic Horizon—Light-colored, leached subsoil horizon

Albic Materials—Soil materials whose color is determined by uncoated primary sand and silt particles

Andic Soil Properties—Unique soil properties associated with materials that are rich in volcanic glass or poorly crystalline minerals

Anhydritic Horizon—Horizon with an accumulation of anhydrite

Anhydrous Conditions—Very cold and very dry soil conditions

Aquic Conditions—Saturation in the soil to the extent that it results in the depletion of oxygen

Aquic Moisture Regime—Regime characteristic of poorly and very poorly drained soils

Argillic Horizon—Subsoil horizon with an illuvial accumulation of clay

Aridic (Torric) Moisture Regime—Regime characteristic of arid and semiarid climates that are unsuitable for cultivation without irrigation

Calcic Horizon—Subsoil horizon with an illuvial accumulation of calcium carbonate ($CaCO_3$)

Cambic Horizon—Subsoil horizon with minimal development

Coefficient of Linear Extensibility (COLE)—A measure describing the proportional change in linear dimension of a soil clod due to shrinking and swelling

Cryic Soil Temperature Class

Cryoturbation—Intense frost churning

Densic Contact—The contact between unconsolidated soil material and the underlying root-restrictive, dense, compact materials

Densic Materials—Root-restrictive, noncemented, dense, compact material

Duripan—Subsoil layer that is cemented by silica

Fibric Soil Materials—Organic soil materials that are only slightly decomposed

Fragipan—A root-restrictive subsoil layer that is firm and brittle, but not cemented

Frigid Soil Temperature Class

Gelic Soil Temperature Class

Gelic Materials—Soil materials (mineral or organic) above permafrost that show evidence of frost churning

Glacic Layer—Layer of ice in the soil

Glossic Horizon—A degrading argillic, kandic, or natric horizon in which loss of clay and iron oxide is occurring

Gypsic Horizon—Surface or subsoil horizon with an accumulation of gypsum

Hemic Soil Materials—Organic soil materials that are moderately decomposed

Human-Altered Materials—Soil material significantly altered by intentional human activity

Human-Transported Materials—Soil material transported by intentional human activity

Hyperthermic Soil Temperature Class

Identifiable Secondary Carbonates—Visible calcium carbonate ($CaCO_3$) that has been precipitated in the soil

Interfingering of Albic Materials—Narrow penetrations of light-colored, leached material into a subsoil horizon

Kandic Horizon—Subsoil horizon with a low nutrient-holding capacity and significantly more clay than the overlying surface layer

Lamellae—Two or more thin layers with accumulation of illuvial clay

Lithic Contact—Contact between unconsolidated soil material and the underlying root-restrictive hard bedrock

Mesic Soil Temperature Class

n Value—A value that describes the ability of a saturated soil to support a load

Natric Horizon—Subsoil horizon with an illuvial accumulation of clay and high levels of sodium

Oxic Horizon—Subsoil horizon that is extremely weathered and has a very low nutrient-holding capacity

Paralithic Contact—Contact between unconsolidated soil material and the underlying root-restrictive soft bedrock

Permafrost—Frozen layer within the soil

Perudic Moisture Regime—Regime in which precipitation exceeds evapotranspiration every month

Petrocalcic Horizon—Root-restrictive subsoil horizon that is cemented by calcium carbonate ($CaCO_3$)

Petroferric Contac—Boundary between unconsolidated soil and a layer cemented with iron

Petrogypsic Horizon—Root-restrictive subsoil horizon that is cemented by gypsum

Placic Horizon—Root-restrictive subsoil horizon that is cemented by iron and organic matter

Plinthite—Subsoil feature consisting of a firm iron-oxide-rich mass that irreversibly hardens after exposure to repeated wet-dry cycles

Redoximorphic Features—Morphological features caused by wetness that are characterized by distinctive reddish and grayish color patterns (also see Aquic conditions)

Salic Horizon—Saline horizon with an accumulation of salts

Sapric Soil Materials—Organic soil materials that are highly decomposed

Slickensides—Subsoil feature consisting of polished and grooved surfaces caused by shrinking and swelling

Soil Moisture Regimes (generalized map)

- Aquic
- Aridic
- Perudic
- Udic
- Ustic
- Xeric

Soil Temperature Regimes (generalized map and classes)

Sombric Horizon—Subsoil horizon with an illuvial accumulation of humus

Spodic Horizon—Subsoil horizon with an illuvial accumulation of organic matter in complex with aluminum and also commonly iron

Spodic Materials—Illuvial, active amorphous materials composed of organic matter in complex with aluminum and also commonly iron

Sulfidic Materials—Soil materials containing acid-producing, oxidizable sulfur compounds

Sulfuric Horizon—Subsoil horizon that has become highly acid due to oxidation of sulfide minerals

Thermic Soil Temperature Class

Udic Moisture Regime—Regime characteristic of humid regions with seasonally well distributed precipitation

Ustic Moisture Regime—Regime characteristic of semiarid climates where moisture is limited but available for portions of the growing season

Xeric Moisture Regime—Regime characteristic of a Mediterranean-type climate, which has cool, moist winters and warm, dry summers

Abrupt Textural Change

A considerable increase in clay content over a short vertical distance

Concept and Background Information

An abrupt textural change is a specific kind of clay increase into an underlying diagnostic subsoil horizon. Only silicate clay (i.e., noncarbonated clay) is considered. The clay increase must occur over a vertical distance of ≤ 7.5 cm and meet a minimum, as follows:

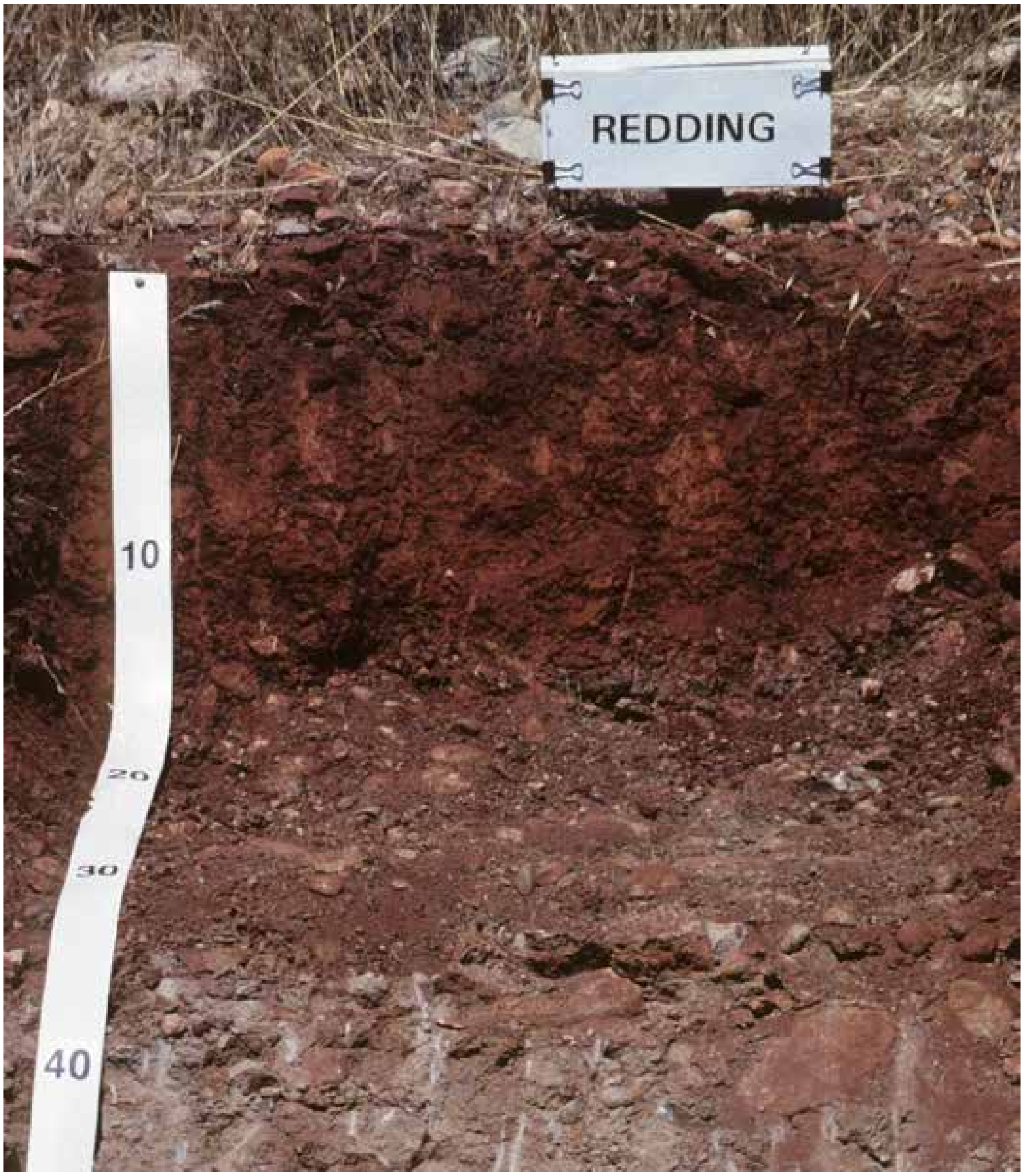
- If the layer above the subsoil horizon has < 20% clay, then the clay content doubles within 7.5 cm. For example, if an E horizon has 15% clay, then clay content is at least 30%.
- If the layer above the subsoil horizon has ≥ 20% clay, then the clay content increases by at least 20% (absolute) within 7.5 cm. For example, if an E horizon has 25% clay, then clay content is at least 45%.

Generalized Characteristics

1) Clay content increases considerably over a vertical distance of ≤ 7.5 cm.
2) The noncarbonated clay content of the subsoil layer is ≥ 8% (by weight).
3) If there is < 20% clay in the eluvial layer, then clay content doubles.
4) If there is ≥ 20% clay in the eluvial layer, then clay content increases by > 20% (absolute).

Common Horizon Nomenclature

An abrupt textural change occurs in the narrow zone of transition from an A or E horizon to the underlying B horizon. There is no horizon nomenclature specifically indicating the presence of an abrupt textural change. Examples of an abrupt textural change include (if the criteria listed above are met) sandy loam over clay, fine sandy loam over silty clay, and loamy sand over sandy clay.



This soil from California has an abrupt textural change from the ochric epipedon to the argillic horizon (at a depth of about 6 inches). The clay increase is not readily apparent visually due to the rather uniform red color. However, it is easily observed tactilely. The soil is an Abruptic Durixeralf (duripan is at a depth of about 20 inches). Scale is in inches.

Back to Abrupt Textural Change

Agric Horizon

Subsoil horizon with an accumulation of silt, clay, and humus

Concept and Background Information

The agric horizon forms in response to cultivation and the subsequent illuvial accumulation of silt, clay, and humus. It is always directly below a plowed surface layer (Ap horizon). After precipitation events, turbulent muddy water moves through large pores in the plow layer. Large connecting pores (such as wormholes), root channels, and voids between peds directly below the plow layer fill with this turbid water. As it moves into the peds, the suspended material (silt, clay, and humus) is left behind to coat the pore surfaces. The illuvial material is dark-colored, generally brown or dark grayish brown to black. Less commonly, the accumulated silt, clay, and humus form thin, continuous lamellae, probably as a result of movement through stratified sandy sediments with contrasting pore sizes between strata.

The agric horizon has only been identified rarely in the United States.

Generalized Characteristics

1) Horizon is directly below a plow layer.
2) Thickness is $\geq$ 10 cm.
3) Horizon has illuvial silt/clay/humus (with color value of $\leq$ 4 moist and chroma of $\leq$ 2) as wormhole linings or thin lenses comprising $\geq$ 5%, by volume.

Common Horizon Nomenclature

The agric horizon is directly below an Ap horizon. Commonly used horizon nomenclature includes master horizon B and various suffixes, including h, t, and w. Examples include: Bh, Bw, and Bt.

Albic Horizon

Light-colored, leached subsoil horizon

Concept and Background Information

The albic horizon is a light-colored (mostly grayish brown to white), eluvial subsoil horizon. It has been leached of clay and free iron-oxides to such a degree that the color of the horizon is mostly due to uncoated sand and silt particles. The albic horizon is generally in a position between a darkened surface layer and an underlying diagnostic horizon (e.g., a cambic, argillic, or spodic horizon). It can also be between two subsoil horizons.

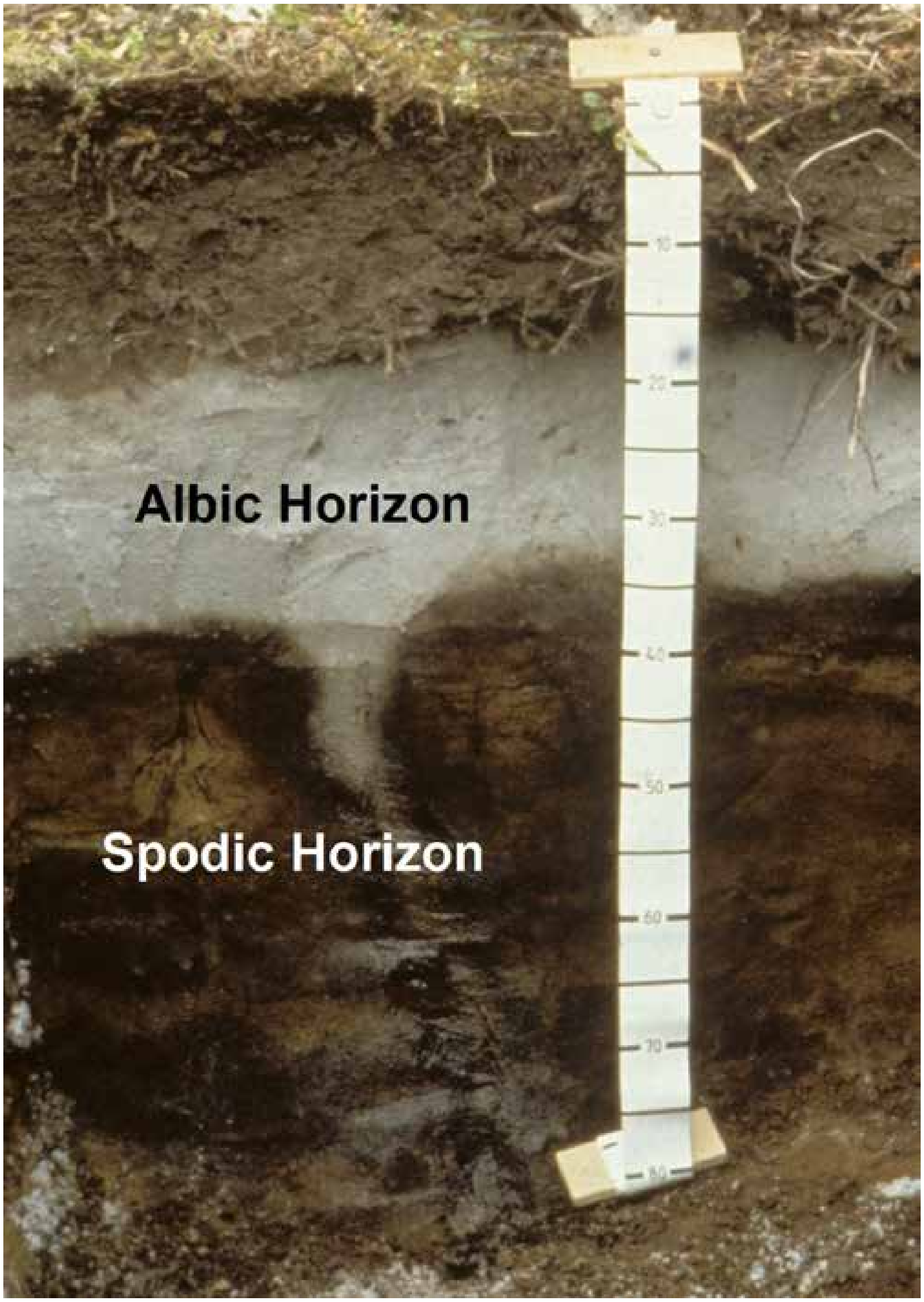
Generalized Characteristics

1) Thickness is ≥ 1 cm.
2) ≥ 85% of the horizon is composed of albic materials. Color is related to uncoated sand and silt grains. Generally, chroma is ≤ 3 and value is ≥ 4 moist and ≥ 5 dry.

Note: Albic materials are eluvial soil materials that have their color determined by the primary silt and sand particles because clay and/or free iron-oxides have been lost. See Albic Materials for specific criteria and for more detailed color criteria.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon E, which may be in combination with one or more suffixes, such as c, g, or x. Examples include: E, Ex, and Ecg.



An albic horizon (white) above a spodic horizon (dark brown) in a soil in New Zealand. Scale is in cm.

Back to Albic Horizon

Albic Materials

Soil materials whose color is determined by uncoated primary sand and silt particles

Concept and Background Information

Albic materials are soil materials that have been subject to eluvial processes to the extent that their color is determined by primary sand and silt particles. They are essentially void of coatings (such as clay and iron oxides). Some parent materials (such as volcanic ash or eolian sands) have colors meeting the definition of albic materials but, unless they are eluviated, they are not considered albic materials. Albic materials are typically found in association with illuvial features in the soil profile, such as an argillic, natric, or spodic horizon.

Generalized Characteristics

Albic materials have one of the following colors:

1) Chroma ≤ 2, *and either*
    a. Value 3 moist and ≥ 6 dry, *or*
    b. Value ≥ 4 moist and ≥ 5 dry, *or*
2) Chroma 3, *and either*
    a. Value ≥ 6 moist, *or*
    b. Value ≥ 7 dry, *or*
3) Hue 5YR or redder, *and either*
    a. Value 3 moist and ≥ 6 dry, *or*
    b. Value ≥ 4 moist and ≥ 5 dry.

Common Horizon Nomenclature

Albic materials may, or may not, be suggested by the horizon nomenclature. Where they make up a significant portion of the horizon, they may be denoted with master horizon E in combination with B. Where they make up the entire horizon (albic horizon), they are noted as E. Examples include: E, B/E, and E/B.

Profile of a soil in Michigan that has a horizon composed of albic materials (albic horizon) in the upper part (white). The white color is indicative of the uncoated sand and silt particles that make up the albic horizon. (Scale is in feet).

Back to Albic Materials

Andic Soil Properties

Unique soil properties associated with materials that are rich in volcanic glass or poorly crystalline minerals

Concept and Background Information

Andic soil properties are characterized by either:

1) Weakly weathered soils that have relatively high contents of volcanic glass and only low to moderate amounts of the minerals that result from weathering of the glass, or
2) Moderately weathered soils that are rich in short-range-order (poorly crystalline) weathering by-products and have lesser amounts of glass remaining.

The common short-range-order (poorly crystalline) minerals include allophane, imogolite, and ferrihydrite. These short-range-order minerals are responsible for imparting andic soil properties to the soil. These properties include a high water-holding capacity, good friability, and low bulk density. In addition, there is a significant propensity to adsorb phosphorus strongly, making it unavailable to plants. Laboratory tests of phosphorus retention and ammonium oxalate extractions of aluminum, iron, and silica are used to infer the relative amounts of the short-range-order minerals.

It is important to note that andic soil properties, while most commonly found in soils of volcanic origin, can also form in other parent materials with no volcanic influence. Andic soil properties in areas with cool, moist climates and abundant carbon may generate organo-metal complexes.

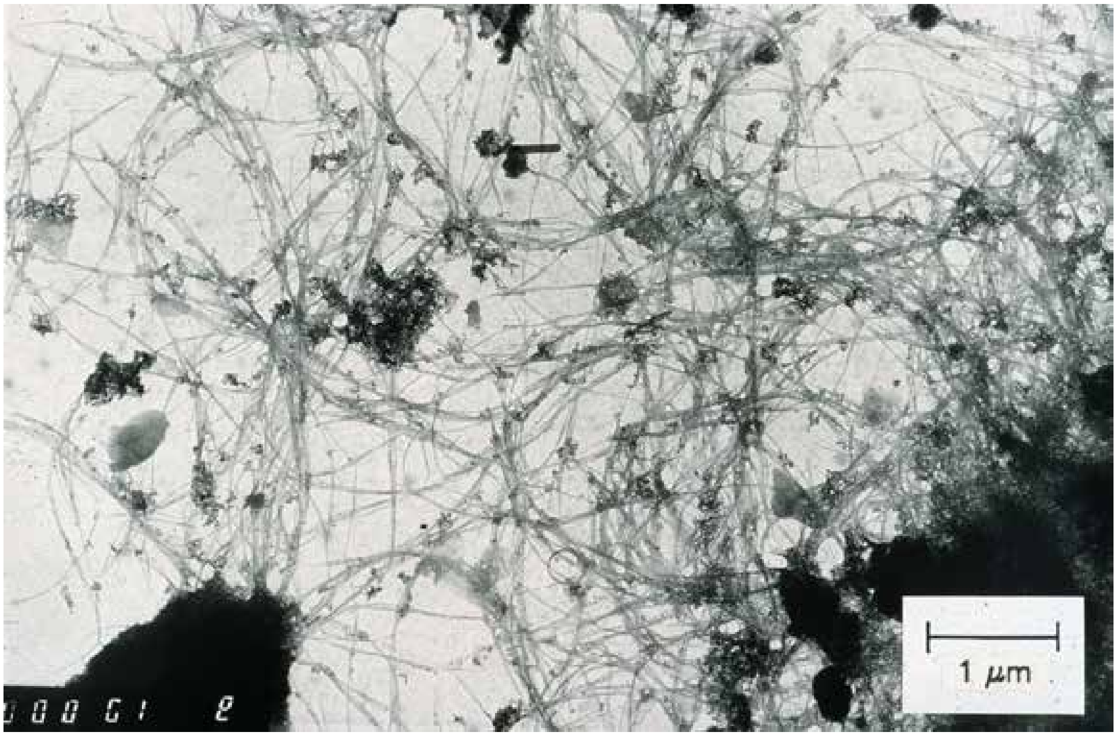
Generalized Characteristics

Soil with andic soil properties:
1) Has $\leq$ 25% organic carbon (by weight), and
2) Meets all of either item A or B:
   A. Has any amount volcanic glass:
      1. Bulk density $\leq$ 0.90 g/cm^3, and
      2. P-retention $\geq$ 85%, and
      3. Al + ½ iron $\geq$ 2.0%,
      OR
   B. Has $\geq$ 5% volcanic glass:
      1. $\geq$ 30% material that is 0.02 – 2.0 mm in size (coarse silt and sand), and
      2. P-retention $\geq$ 25%, and

3. Al + ½ iron $\geq$ 0.4%, and
4. [(Al + ½ iron %) X 15.625] + (glass %) $\geq$ 36.25

Common Horizon Nomenclature

There is no horizon nomenclature indicating the presence of andic soil properties. They are most often associated with O, A, or B horizons in soils of volcanic origin but can only be confirmed with laboratory data.



Andic soil properties can only be documented through laboratory analysis. Many soils with andic soil properties have an abundance of "short-range order" minerals which impart unique properties to the soil. This transmission electron micrograph shows the mineral imogolite. It is from a soil that contains volcanic ash in the Cascade Range of Washington State. Note the non-crystalline, filament-like shape. (Photo courtesy of Dr. Randy Dahlgren)

Back to Andic Properties

Anhydritic Horizon

Horizon with an accumulation of anhydrite

Concept and Background Information

The anhydritic horizon is a horizon in which anhydrite ($CaSO_4$) has accumulated either through direct formation or as a transformation (dewatering) of gypsum ($CaSO_4$ $2H_2O$). It typically occurs as a subsurface horizon and is commonly associated with a salic horizon.

Generalized Characteristics

1) Thickness is $\geq$ 15 cm.
2) Anhydrite is the dominant calcium sulfate mineral present and its content is $\geq$ 5% (by weight), and
    a. (Anhydrite % wt.) X (thickness in cm) $\geq$ 150. (For example, if gypsum is 6% and thickness is 20 cm: 6% gypsum X 20 cm = 120; example fails anhydritic.)
3) Horizon has hue of 5Y with chroma of 1 or 2 (moist or dry) and value of 7 or 8.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon A or B and suffix y or yy. In some cases, suffix k or z may also be used. Examples include: Ayy, Byk, and Ayz.

Profile of a soil in the United Arab Emirates that has an anhydritic horizon (white layer at a depth of 0 to about 60 cm). Depth is in cm. (Photo courtesy of Dr. Shabbir A. Shahid**)**

Back to Anhydritic Horizon

Anhydrous Conditions

Very cold and very dry soil conditions

Concept and Background Information

Anhydrous conditions occur in very cold deserts. Precipitation tends to be very low, generally < 50 mm per year. Consequently, the soil is very dry (generally < 3% moisture, by weight).

Generalized Characteristics

1) Mean annual soil temperature is $\leq$ 0 °C.
2) At a depth of 10 to 70 cm:
    - *a.* Temperature is < 5 °C all year, *and*
    - b. Soil has no ice-impregnated permafrost, *and*
    - c. When temperature is $\geq$ 0 °C ($\geq$ 1500 kPa tension), soil is very dry, *or*
    - d. When temperature is $\leq$ 0 °C, soil is loose to just slightly hard (unless there is pedogenic cementation).

Common Horizon Nomenclature

There is no horizon nomenclature indicating the presence of anhydrous conditions. Under such extreme conditions, most master horizons are C in combination with suffix ff, for example, Cff. *Note: Suffix ff is also used in cases that are not extreme enough to qualify for anhydrous conditions.*

A soil climate monitoring station in the cold, dry desert of the Wright Valley of Antarctica at the base of Bull Pass (elevation of 150 m). The soil is an Anhyorthel.

Return to Anhydrous Conditions

Aquic Conditions

Saturation in the soil to the extent that it results in the depletion of oxygen

Concept and Background Information

Aquic conditions are characterized by saturation that is of long enough duration to result in the depletion of oxygen by microbes, thus becoming anaerobic. The time required to deplete oxygen is unique to each site. It generally occurs faster in warmer environments than in colder ones but is generally a few days or weeks. In the anaerobic environment, microbes must rely on elements other than oxygen to carry out their metabolism. In so doing, these elements are “reduced” (i.e., they gain an electron). Two important elements involved in this process are manganese and iron. When these elements are converted from their oxidized state to their reduced state, they become mobile and move in solution within the soil. As a result, manganese and iron ions tend to move along a gradient from areas within the soil that are void of oxygen to areas (such as faces of peds and pores) where oxygen is present. In the oxygenated areas, the ions are returned to their oxidized state (i.e., they lose an electron) and are immobilized. This process is marked by the formation of redoximorphic features in the soil. Areas depleted of iron and manganese tend to be gray in color, forming redox depletions, while areas where the iron and manganese have accumulated are redder (or black for manganese), forming redox concentrations. To be recognized as having aquic conditions, there must be periodic saturation by water, reducing conditions strong enough to reduce iron, and the presence of redoximorphic features. Aquic conditions may occur throughout the soil profile or in one or more layers anywhere within the soil profile.

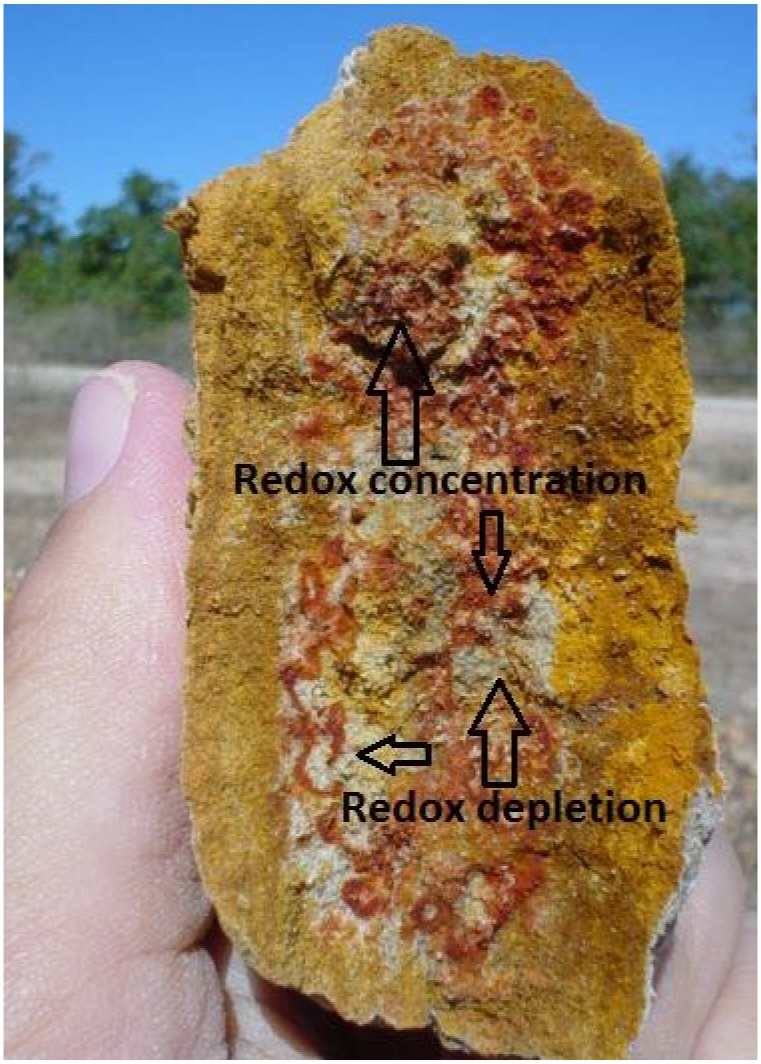
Link to Aquic Moisture Regime

Generalized Characteristics

Soils with aquic conditions have:
1) Saturation by water, *and*
2) Reducing (anaerobic) conditions, *and*
3) Presence of redoximorphic features.

Common Horizon Nomenclature

There is no horizon nomenclature specifically indicating the presence of aquic conditions. Master horizons can be O, A, E, B, C, or L. Suffix a is commonly used with O, and suffix g (alone or in combination with other suffixes) is used with the other master horizons if aquic conditions exist. Examples include: Oa, Btg, and Cg.



Redoximorphic features in a periodically saturated and reduced soil near College Station, Texas. Redox depletions are gray; redox concentrations are red or yellow. (Photo courtesy of Dr. David Weindorf)

Return to Aquic Conditions
Return to Redoximorphic Features

Aquic Moisture Regime

Regime characteristic of poorly and very poorly drained soils

Concept and Background Information

The aquic soil moisture regime occurs in poorly drained and very poorly drained soils that are saturated close to the surface when soil temperatures are warm enough to allow microbial activity to occur (generally ≥ 5 degrees C) and for periods that are long enough to result in the near depletion of dissolved oxygen.

Soil Taxonomy does not use the aquic moisture regime as a criterion in any taxa. Rather it uses the identification of aquic soil conditions at specific depths to define some taxa. However, it is appropriate to identify an aquic soil moisture regime in soil descriptions.

See the generalized map of the soil moisture regime regions in the continental United States.

Generalized Characteristics

1) Saturation and reduction of the upper part of the soil occur to the extent that the soil is virtually free of dissolved oxygen.

Note: For information regarding the estimation of this criterion, see the discussion of soil moisture regimes in Part 1—How to Use This Version of the Keys.

The soils adjacent to this open water area are saturated near the surface and have an aquic soil moisture regime.

Return to Aquic Moisture Regime

Argillic Horizon

Subsoil horizon with an illuvial accumulation of clay

Concept and Background Information

The argillic horizon forms as a result of the translocation of clay from an eluvial layer (generally near the surface) into the subsoil, where it accumulates in the argillic horizon. As a result, the argillic horizon has a significantly higher content of clay than the layer(s) above. Not all of the increase in clay content from the surface layers to the argillic horizon may be due to the physical movement (illuviation) of clay into the argillic horizon. Other processes, such as the chemical dissolution of clay in the surface layers, selective erosion of the finer (clay) particles from the surface layers, and the chemical formation of clay within the argillic horizon, can also contribute to the increase in clay content. Illuviation of clay, however, is responsible for at least some of the increase.

Generalized Characteristics

1) Thickness is ≥ 7.5 cm (≥ 15 cm if horizon is sandy or composed of lamellae).
2) There is evidence of clay illuviation, *either:*
    a. Field evidence (clay films in pores or on peds or clay bridging of sand grains), *or*
    b. Laboratory evidence (oriented clay in thin section or significantly more fine clay [as a fraction of total clay] in the argillic horizon as compared to the eluvial layer above.
3) Clay percent increases significantly within a vertical distance of ≤ 30 cm. (Minimum required increase ranges from 3 to 8 percent, depending on the clay content of the eluvial layer.)

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B and suffix t, alone or in combination with other suffixes, such as g, k, n, ss, v, or x. Examples include: Bt, Btg, Btk, and Btv.

Clay films (slightly darker red) on surfaces of peds throughout an argillic horizon. (Photo courtesy of John Kelley)

Back to Argillic Horizon

Clay bridging of sand grains.

Aridic (Torric) Moisture Regime

Regime characteristic of arid and semiarid climates that are unsuitable for cultivation without irrigation

Concept and Background Information

The aridic soil moisture regime is a very dry regime in which not enough water moves through the soil to leach minerals from the profile. Soluble salts, if present in the parent materials or if introduced by dust or other sources, tend to accumulate in some of these soils. Soils that occur in the slightly wetter semiarid regions but have an aridic moisture regime have some restriction to infiltration of precipitation, such as steep slopes or a surface crust. Not included in the aridic soil moisture regime are soils in very cold, very dry polar regions or at high elevations that have anhydrous conditions. The terms “aridic” and “torric” refer to the same soil moisture regime but are used in different categories in Soil Taxonomy.

See the generalized map of soil moisture regimes in the continental United States.

Generalized Characteristics

1) During the growing season:
    a. The soil is dry more than half of the total days.
    b. The soil is moist < ~ 90 consecutive days.

See the discussion of soil moisture regimes in Part 1—How to Use This Version of the Keys.

Small-scale farm plots of hay for forage and date palms (green vegetation) in United Arab Emirates. Large dunes are in the background. This area has an aridic soil moisture regime. Growing crops in these dry areas requires access to water for irrigation. Management of salts to avoid salinization is a common concern. (Photo courtesy of John Kelley)

Return to Aridic Moisture Regime

Calcic Horizon

Subsoil horizon with an illuvial accumulation of calcium carbonate

Concept and Background Information

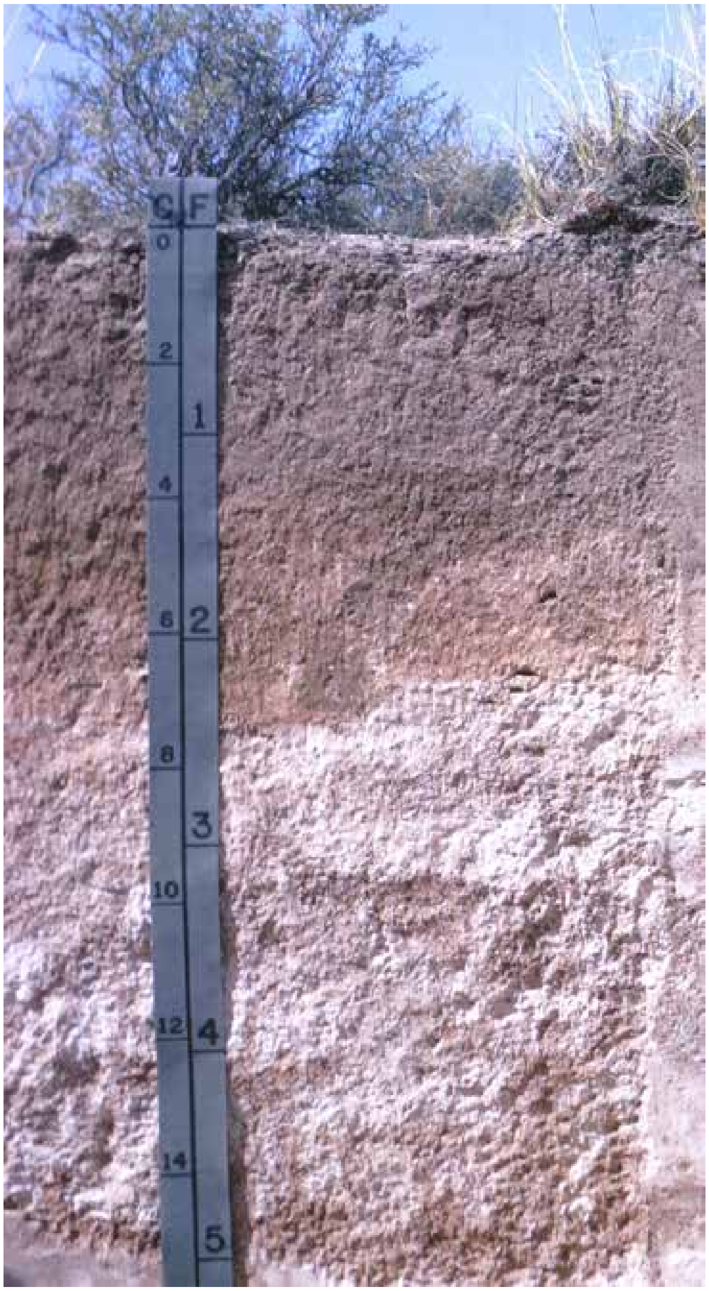
The calcic horizon is a subsoil horizon with a significant illuvial accumulation of calcium carbonate. Evidence for the pedogenic accumulation of calcium carbonate ($CaCO_3$) is either the presence of secondary forms, such as masses, threads coatings, pendants, or nodules, or a calcium carbonate equivalent that is higher than that of the underlying horizon. The carbonates typically have moved downward in solution with the percolating waters and subsequently reprecipitated and accumulated at the wetting front. In some soils with a water table, the calcium carbonate may move upward due to capillary rise and accumulate as the water evaporates. The calcic horizon generally has no cementation, but the definition includes layers with cementation that is not sufficiently developed to meet the criteria for a petrocalcic horizon. Calcic horizons are commonly found in arid or semiarid environments where limited precipitation only moves soluble salts, including calcium carbonate, though the soil as a function of depth of moisture penetration.

Generalized Characteristics

1) Thickness is ≥ 15 cm.
2) Calcium carbonate equivalent is ≥ 15% (or ≥ 5% if the horizon has < 18% clay and ≥ 15% sand) and horizon *either:*
    a. Is 5% higher by weight (absolute) than an underlying horizon, *or*
    b. Has ≥ 5%, by volume, visible secondary $CaCO_3$ forms (such as masses, threads, coatings, and nodules).
3) Horizon has no (or minimal) cementation (air-dry fragments disintegrate when submerged in water).

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon A or B and suffix k or kk, alone or in combination with other suffixes, such as n, q, y, or z. Examples include: Ak, Bk, and Bkknz.



Profile of a soil in New Mexico. A calcic horizon is below a depth of about 75 cm. The white color is due to calcium carbonate concentrations. Scale is in 10-cm increments (left) and feet (right).

Back to Calcic Horizon

Cambic Horizon

Subsoil horizon with minimal development

Concept and Background Information

The cambic horizon is a subsoil horizon with minimal development. Development is evidenced either by physical alteration, chemical transformation, removal of soil constituents, or a combination of these. Physical alteration is commonly the result of processes like freezing and thawing, shrinking and swelling, and biological activity to the extent that most rock structure is obliterated. In addition, the alteration commonly includes the formation of soil structural units (peds). Chemical transformation includes processes such as the reduction of iron, manganese, and other elements under anaerobic conditions in wet soils, the weathering of primary minerals to form clays and/or sesquioxides, and/or the dissolution and redistribution of salts (such as calcium carbonate and gypsum) into secondary forms in the horizon. Removal of constituents originally present in the parent material includes the leaching of materials such as calcium carbonate and gypsum from the layer.

The common feature of all cambic horizons is the loss of at least half of their original rock structure. Most cambic horizons have some degree of soil structure but, if they formed in contrasting environments, can look quite different from each other. For example, in well drained, humid climates, the cambic horizon commonly occurs as a bright-colored and/or slightly reddened layer (due to the accumulation of sesquioxide coatings). Under saturated conditions, the cambic horizon has red and gray iron accumulations and depletions (redoximorphic features) as a common characteristic. In semiarid and arid environments, many cambic horizons have redistribution and/or loss of soluble salts.

Generalized Characteristics

1) Thickness is $\geq$ 15 cm.
2) Texture is loamy or clayey (i.e., very fine sand, loamy very fine sand, or finer).
3) Horizon has evidence of alteration (pedogenesis) as follows:
    a. Soil structure (or at least loss of rock structure in > 50% of the volume), *and*
    b. In wet soils (those periodically saturated within 50 cm of the soil surface):
        i. Gray colors and no color change on exposure to air, *and*
            1. Value $\leq$ 3 and chroma = 0, *or*
            2. Value $\geq$ 4 and chroma $\leq$ 1, *or*

            3. Any value and chroma < 2, plus redox concentrations (reddish mottles).
    c. In “non-wet” soils (those not saturated within 50 cm of the soil surface):
        i. When compared to the horizon above or below:
            1. Higher value or chroma, *or*
            2. Redder hue, *or*
            3. Higher clay content, *or*
        ii. Carbonates or gypsum have been removed.

4) Horizon is not significantly brittle (i.e., it deforms gradually when compressed).

Note: The cambic horizon cannot also meet the requirements for an anthropic, histic, folistic, melanic, mollic, plaggen, or umbric epipedon; for a duripan or fragipan; or for an argillic, calcic, gypsic, natric, oxic, petrocalcic, petrogypsic, placic, salic, spodic, or sulfuric subsoil horizon.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B and suffix g, ss, or w. However, many other suffixes can be applied (such as h, k, n, o, q, s, ss, t, or x) so long as the properties noted do not meet the criteria for any other diagnostic horizon. Examples include: Bw, Bg, and Bk.

In this soil, the cambic horizon has subangular blocky structure and redder hue and higher chroma than the overlying ochric epipedon. It also has a lower carbonate content than the horizons below (not visible in photo). The soil is a Haplocambid in the United Arab Emirates. (Photo courtesy of Dr. Craig Ditzler)

Back to Cambic Horizon

Coefficient of Linear Extensibility (COLE)

A measure describing the proportional change in linear dimension of a soil clod due to shrinking and swelling

Concept and Background Information

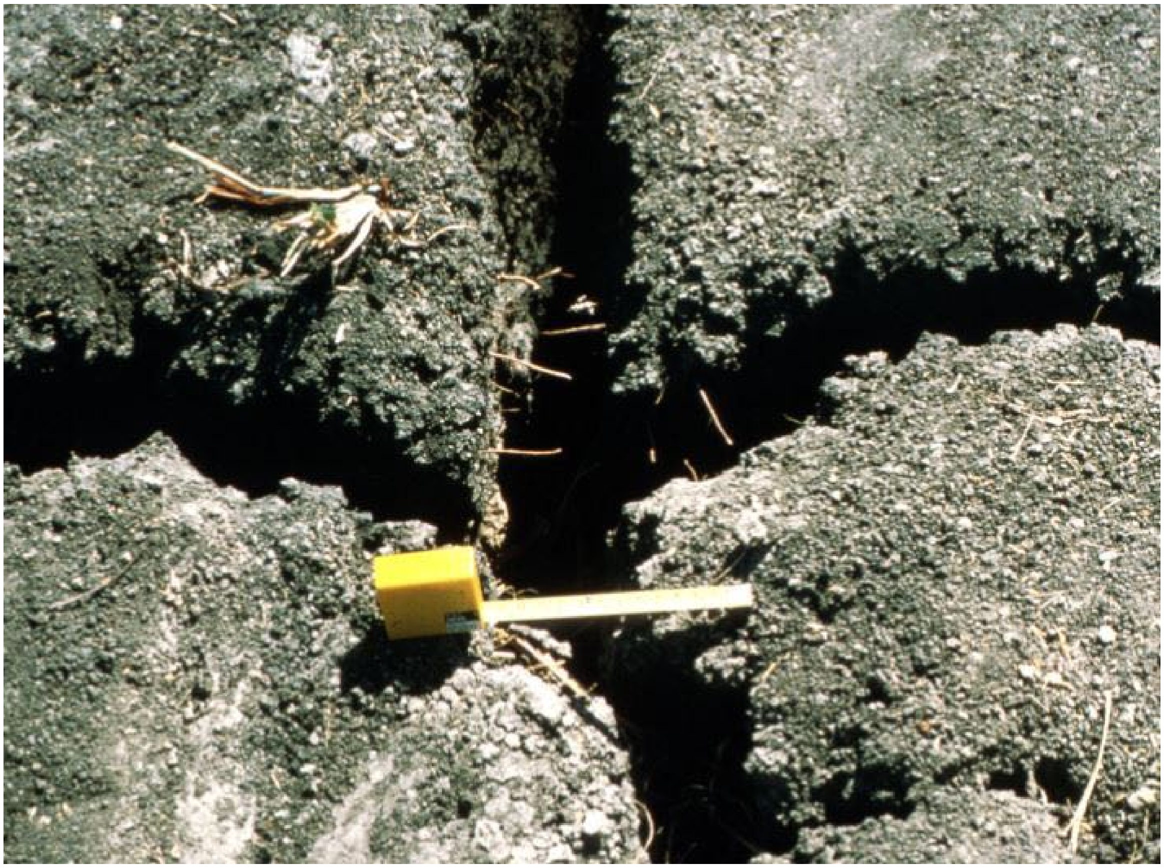
The coefficient of linear extensibility (COLE) is a measure describing the proportional change in linear dimension of a soil clod due to shrinking and swelling. Higher values indicate greater potential for soil movement due to shrinking and swelling. COLE is used in the criteria for argillic and natric horizons to identify conditions with high shrink-swell potential (COLE $\geq$ 0.4) where the visual evidence of clay illuviation (such as oriented clay as clay films on faces of peds and in pores) is likely to be destroyed due to soil movement.

COLE is calculated as:

$$\text{COLE} = (\text{length}_{(\text{moist})} - \text{length}_{(\text{dry})}) / \text{length}_{(\text{dry})}$$

In the laboratory, COLE is derived by simply taking the difference between the bulk density measurements for moist and oven-dry states. It can be estimated in the field by placing two pins in a clod at field capacity and observing the change in distance between the pins at the air-dry state.

Note: A similar property (linear extensibility, or LE) is used at the subgroup level of Soil Taxonomy.



Coefficient of linear extensibility is a quantitative measure describing a soil's potential for shrinking and swelling. In extreme cases, large cracks can form when the soil dries, as in this photo.

Return to COLE

Cryoturbation

Intense frost churning

Background Information

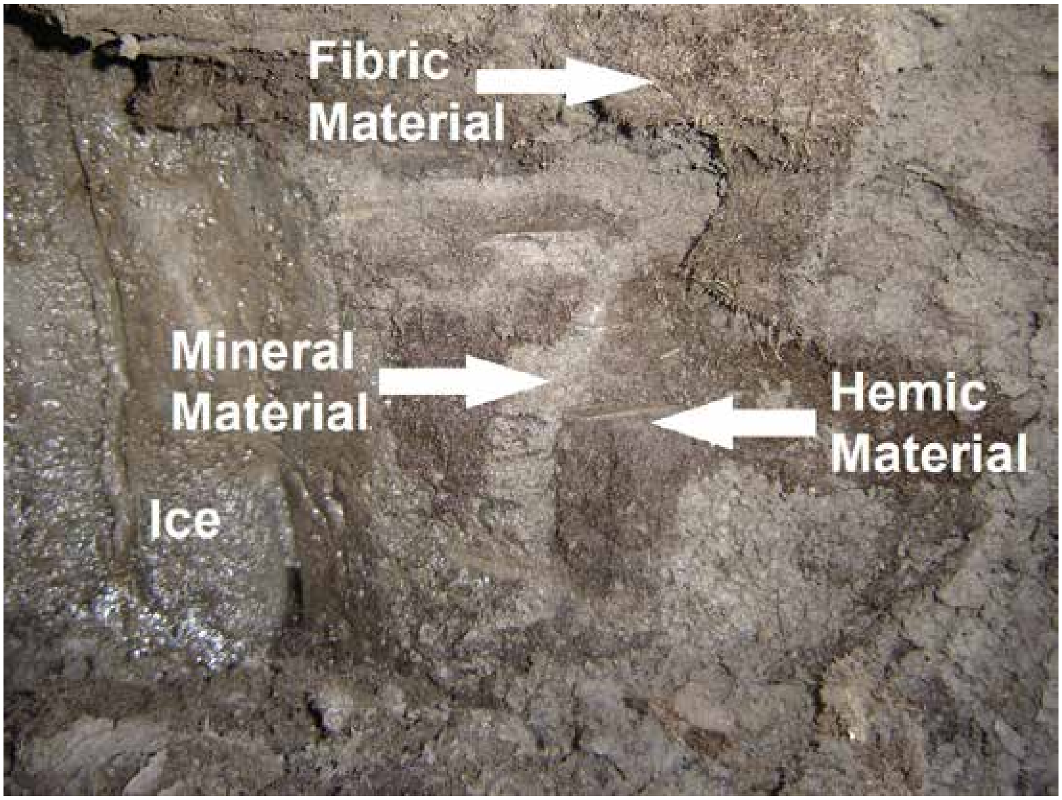
Cryoturbation is the mixing of the soil as a result of intense frost churning due to freeze-thaw cycles. (See Gelic Materials)

Generalized Characteristics

1) Evidence of cryoturbation includes:
    a. Irregular or broken horizons.
    b. Involutions.
    c. Organic matter accumulation on the permafrost table.
    d. Orientated rock fragments.
    e. Silt caps on rock fragments.

Common Horizon Nomenclature

Cryoturbation is specifically indicated by use of the suffix jj. It can be associated with any of the master horizons O, A, E, B, C, or L, which may be combined to reflect the mixing (such as O/A and B/C). Examples include: O/Ajj, Bjj, and Bjjg.



Cryoturbated organic materials in the subsoil of a low-centered polygon rim in northern Alaska. (Photo courtesy of Dr. David Weindorf)

Back to Cryoturbation

Densic Contact

The contact between unconsolidated soil material and the underlying root-restrictive, dense, compact materials

Concept and Background Information

The densic contact is the boundary between unconsolidated soil material and the underlying root-restrictive, noncemented, dense and compact layer. Since it is not cemented, an air-dry fragment will slake in water. See Densic Materials.

Generalized Characteristics

1) The contact is to a dense, compact, noncemented layer.
2) Spaces where roots can penetrate are more than 10 cm apart

Common Horizon Nomenclature

A densic contact is commonly identified at the upper boundary of some horizons (A, E, B, or C) by the suffix d. Examples include: Bd, Cd, and ^Cdu.

Densic Materials

Root-restrictive, noncemented, dense, compact material

Concept and Background Information

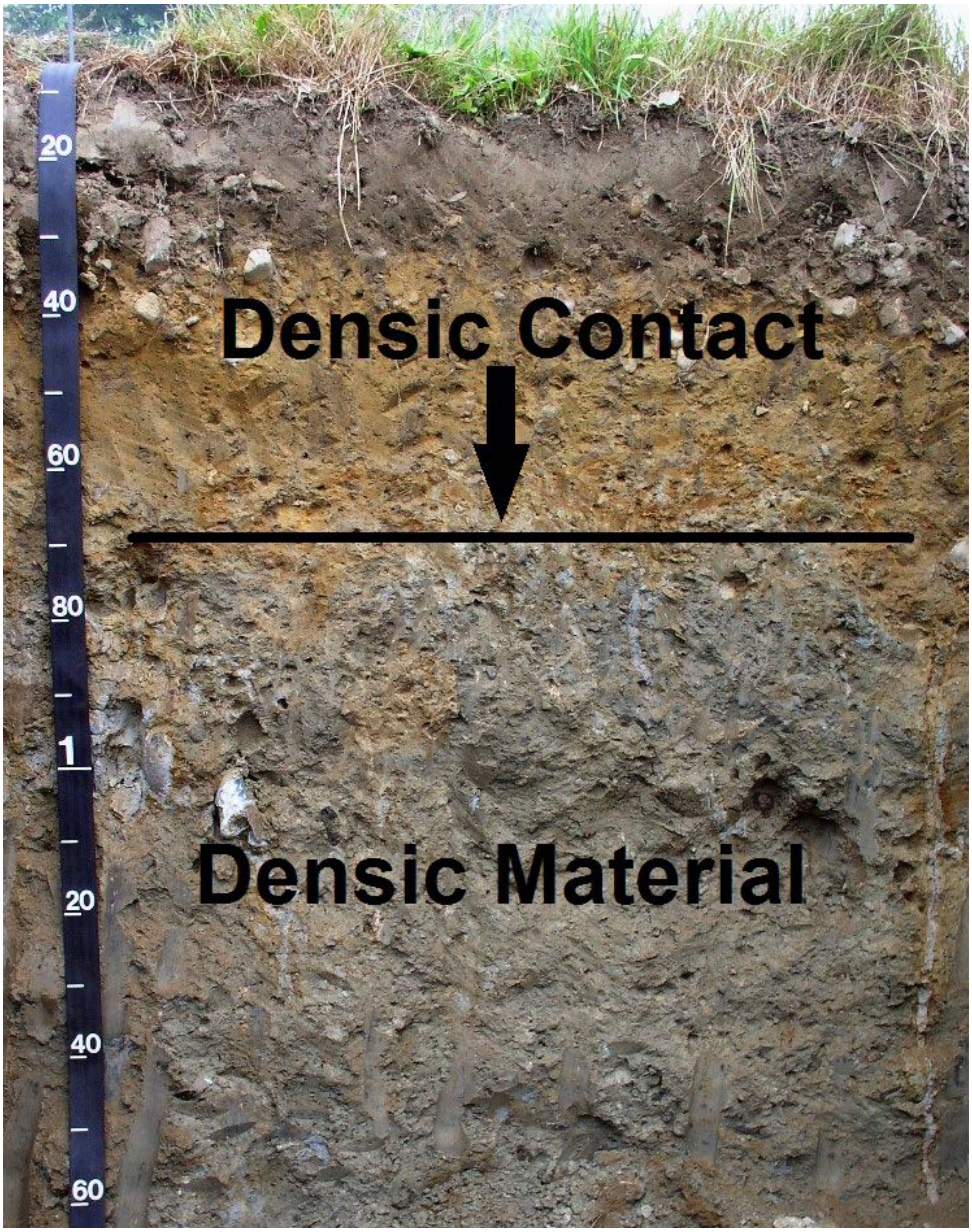
Densic materials are root-restrictive, noncemented, dense, and compact. They do not meet the definition of any diagnostic horizon (e.g., a fragipan). Densic materials are not cemented, so an air-dry fragment will disintegrate in water. Spaces where roots can penetrate are more than 10 cm apart. Densic materials occur naturally in materials such as glacial till and volcanic mudflows. However, they can also result from human activities that cause significant compaction of unconsolidated soil material (natural or human-transported).

Generalized Characteristics

1) Materials do not meet criteria for any diagnostic horizon.
2) Spaces where roots can penetrate are more than 10 cm apart.
3) Materials are noncemented.

Common Horizon Nomenclature

Densic materials are commonly identified in some horizons (A, E, B, and C) by the suffix d. Examples include: Bd, Cd, and ^Cdu.



Profile of a soil in Rhode Island that has a densic contact at a depth of about 70 cm. The densic materials (gray) below this depth consist of root-restrictive, dense, compacted lodgment glacial till. Scale is in cm.

Return to Densic Contact
Return to Densic Materials

Duripan

Subsoil layer that is cemented by silica

Concept and Background Information

The duripan is a root-restrictive subsoil layer that is primarily cemented by illuvial silica. Other cementing agents, such as calcium carbonate, may also be present. Duripans occur in areas where silica may be illuviated into the subsoil but is not removed entirely from the profile. These conditions may occur in arid or semi-arid regions with seasonal wetness. Duripans are commonly associated with volcanic materials, such as ash deposits, which supply ample silica as they weather. They are also associated with other silica-supplying, non-volcanic parent materials, especially those with ferromagnesian minerals and feldspars.

Generalized Characteristics

1) More than 50% of the layer is cemented with illuvial silica.
2) The slake test (air dry in 1N HCl) results in < 50% dissolution of cemented fragments.

Note: There is no minimum thickness requirement for the duripan. The slake test is used to confirm that silica is the main cementing agent. Calcium carbonate cement will be dissolved by 1N HCl. To dissolve silica cement, concentrated KOH or NaOH is required.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B and suffixes q and m used together, with or without other suffixes. Examples include: Bqm and Bkqm.

A duripan in a Haplodurid near Culberson County, Texas. Rock fragments in photo are medium to coarse gravel in a silica-cemented matrix. (Photo courtesy of Dr. David Weindorf)

Back to Duripan

Fragipan

A root-restrictive subsoil layer that is firm and brittle, but not cemented

Concept and Background Information

The fragipan is a root- and water-restrictive subsoil layer that is firm and brittle but not cemented. Air-dry fragments mostly slake in water, thus confirming the absence of a cementing agent. Fragments are firm or harder when dry. When moist, they have a brittle manner of failure when increasing pressure is applied (they rupture suddenly rather than deform gradually). The fragipan is commonly located below an argillic, cambic, or spodic horizon. It commonly has sufficient illuvial clay to also be an argillic horizon. Many fragipans have vertical ped surfaces coated with light-colored eluvial material that form a polygonal pattern when viewed in cross-section on a horizontal plane. The streaks commonly surround brittle, browner material that has redoximorphic features in the form of iron-manganese accumulations. Most fragipans restrict water movement, and water perches above them. Fragipans commonly form in transported parent materials. They are generally loamy in texture and commonly have a lithologic discontinuity.

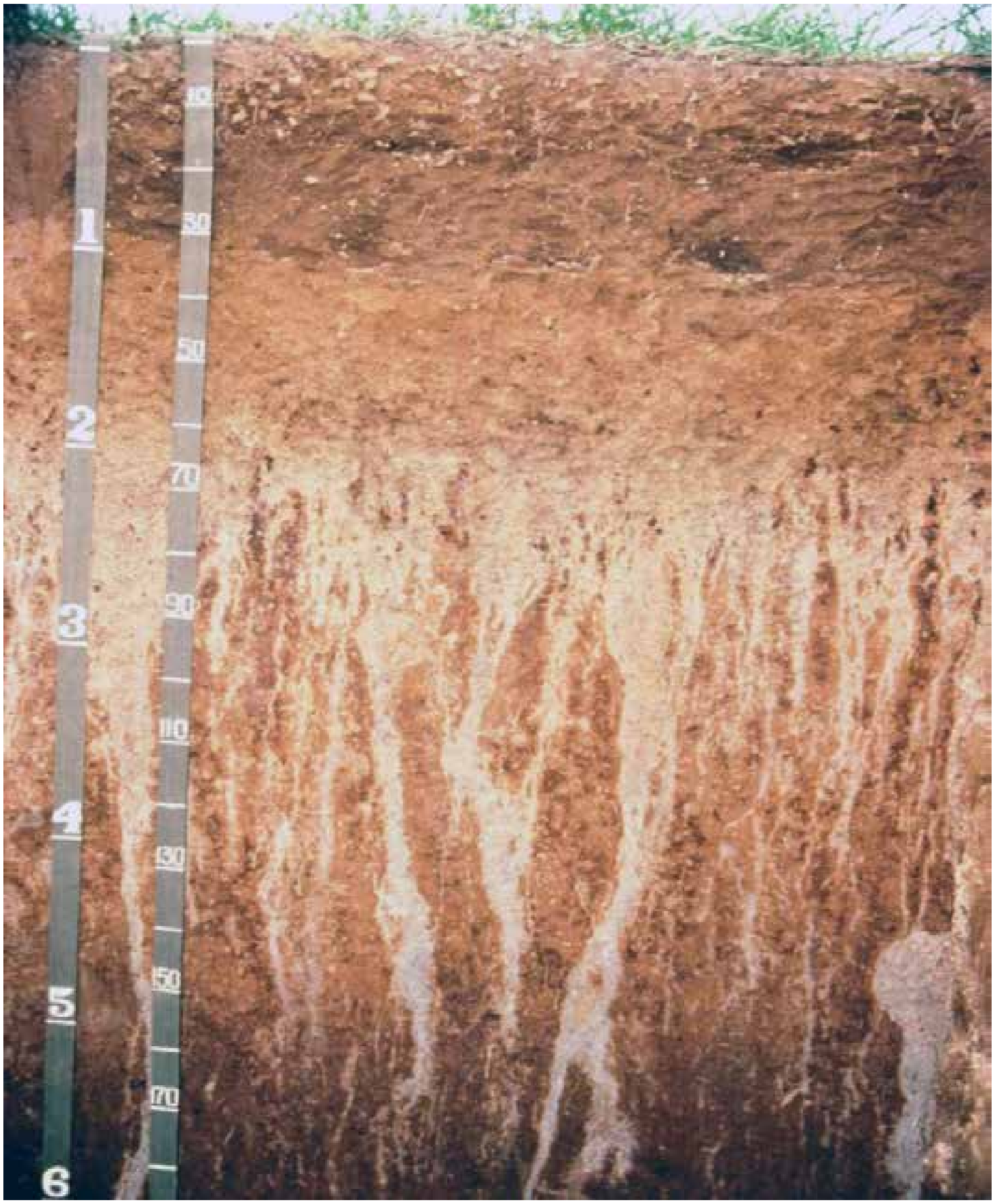
Generalized Characteristics

1) Thickness is ≥ 15 cm.
2) Layer has evidence of pedogenesis (e.g., it is not simply mechanically compacted).
3) Layer has structure that does not allow roots to penetrate at spaces less than 10 cm apart, or it is massive.
4) Layer is not cemented (air-dry fragments mostly disintegrate when submerged in water).
5) In > 60% of volume, peds are firm or hard and brittle when moist.
6) Layer is noneffervescent in dilute HCl.

Note: Evidence of pedogenesis includes features such as oriented clay, albic materials, structure, and redoximorphic features.

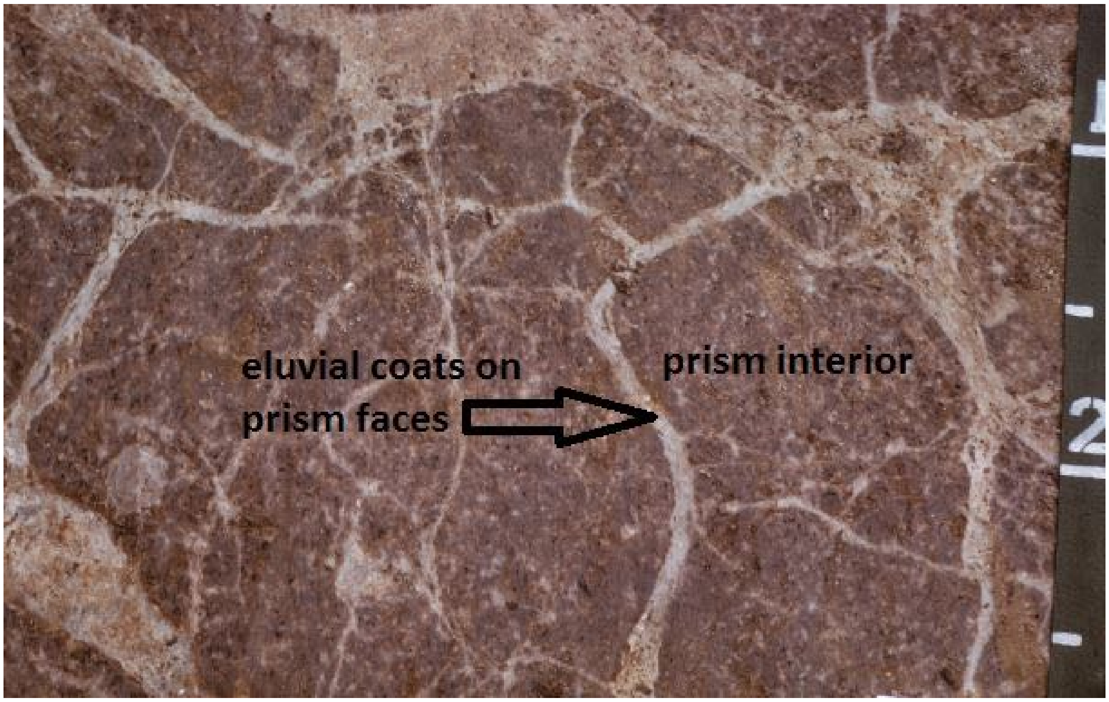
Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B, and less commonly E, combined with suffix x. Additional suffixes, such as g and t, may also be used. A number prefix denoting a lithologic discontinuity is often used for fragipans. Examples include: Ex, 2Btx, and Bxg.



Profile a Fragiudalf (in Tennessee) that has a fragipan below a depth of about 60 cm. The gray soil material consists of eluvial coatings surrounding the browner soil material of the prism interiors. Scale is in feet (left) and centimeters (right).

Back to Fragipan



Horizontal cross-section through a fragipan with prismatic structure. View is from above. Soil is a Fragiudalf in Tennessee. Scale is in feet.

Back to Fragipan

Fibric Soil Materials

Organic soil materials that are only slightly decomposed

Concept and Background Information

Fibric soil materials are organic soil materials that are only slightly decomposed. They have high amounts of fibers that can be identified as to their biological origin. Three quarters or more of intact fibers remain after rubbing. Fibric materials tend to be found in cool, moist environments with rates of decomposition relatively slow compared to the rate of organic matter accumulation.

A simple field test involves rubbing the material between the fingers (about ten times) to observe the amount of intact fiber that persists after rubbing. Fibric soil materials generally have low bulk density (<~0.1 g/cm^3) and a high water content when saturated (commonly ~850 - > 3,000%, by weight, compared to oven dry). Fibric soil materials are commonly light yellowish brown, dark brown, or reddish brown.

Note: For comparison, see the more decomposed hemic and sapric soil materials.

Generalized Characteristics

Materials contain:

1) $\geq$ 3/4 (by volume) fibers after rubbing *or*
2) $\geq$ 2/5 fibers and yield a light gray to very pale brown extract of sodium pyrophosphate solution.

Note: Fibers are > 0.15 mm in cross-section, show evidence of cellular structure, and are < 20 mm in the smallest dimension (or can easily be crushed to this size).

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon O with suffix I (i.e., Oi).

Organic soil materials, including fibric (top), hemic (middle), and sapric (lower) materials. (Photo courtesy of John Kelley)

Return to Fibric Soil Materials

Gelic Materials

Soil materials (mineral or organic) above permafrost that show evidence of frost churning

Concept and Background Information

Gelic materials are soil materials (mineral or organic) that show evidence of frost churning (see Cryoturbation). Gelic materials formed as a result of cryopedogenic processes occurring in the periodically frozen soil layers above the permafrost. These processes include volume changes associated with water/ice transformations, movement of moisture across thermal gradients in the frozen soil, and thermal contraction during continued rapid cooling episodes.

Generalized Characteristics

Gelic materials have:

1) Macro structural evidence that includes:
    a. Platy, blocky, or granular peds.
    b. Particle sorting, as in patterned ground.
2) Micro structural evidence that includes:
    a. Orbiculic, conglomeric, banded, or vesicular soil fabric types.
3) Ice segregations in the form of:
    a. Ice lenses, vein ice, segregated ice crystals, or ice wedges.

Common Horizon Nomenclature

Gelic materials are commonly indicated by use of suffix jj in horizons above a permafrost layer. They can be associated with any of the master horizons O, A, E, B, C or L, and these may be combined to reflect the mixing (O/A, B/C, etc.). Examples include: O/Ajj, Bjj, and Bjjg.

A layer with gelic materials from a soil in Alaska. The presence of ice crystal segregations and ice lenses is evidence of gelic materials. (Photo courtesy of Dr. David Weindorf)

Return to Gelic Materials

Glacic Layer

Layer of ice in the soil

Concept and Background Information

A glacic layer is a layer composed primarily of ice in the soil.

Generalized Characteristics

1) Thickness is ≥ 30 cm.
2) Layer contains ≥ 75% visible ice.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon W and suffix f (i.e, Wf).

An ice wedge forms a glacic layer in a frozen soil in Alaska. (Photo courtesy of Dr. David Weindorf)

Glossic Horizon

A degrading argillic, kandic, or natric horizon in which loss of clay and iron oxide is occurring

Concept and Background Information

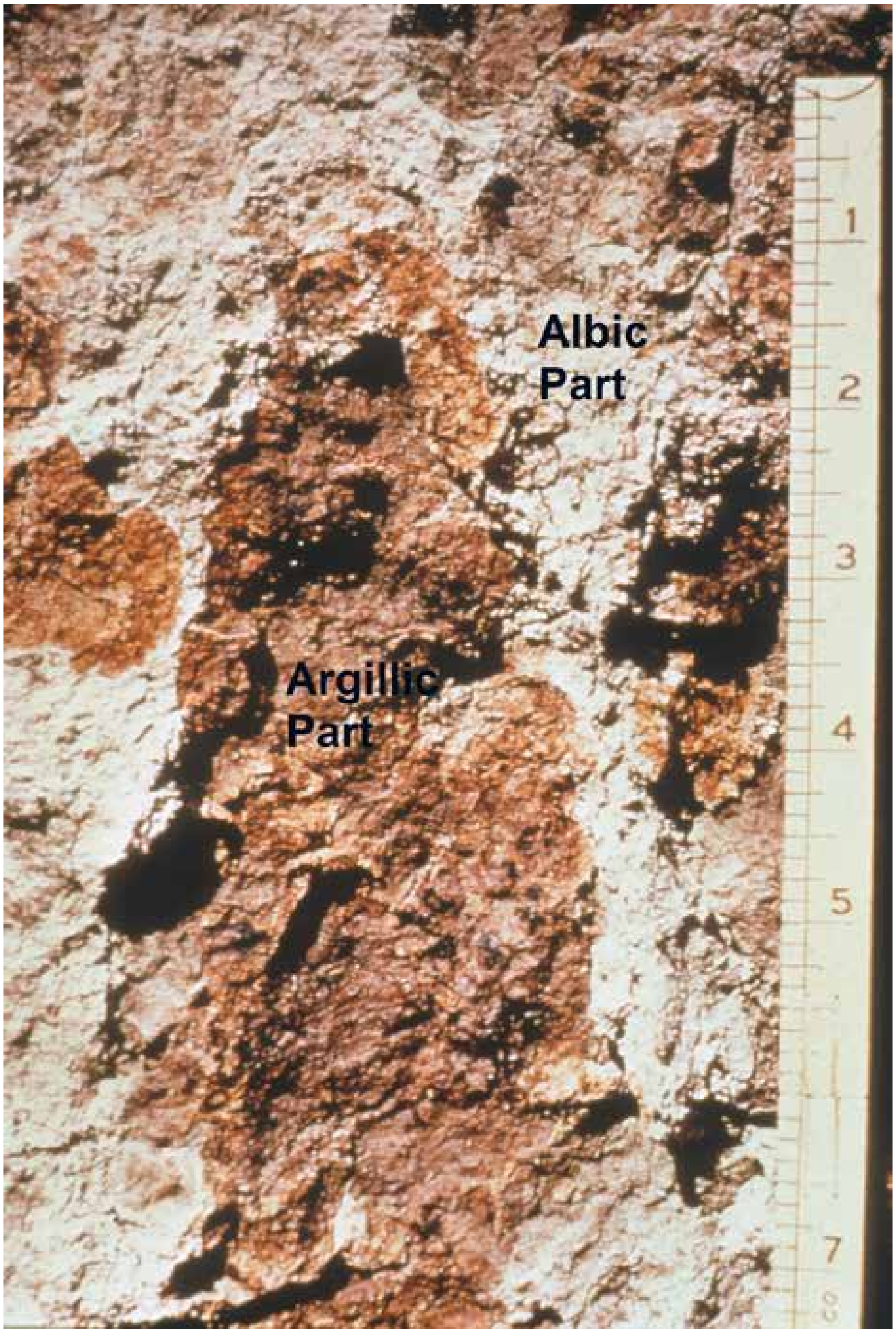
The glossic horizon is a degrading argillic, kandic, or natric horizon. In this horizon, eluviation of clay and iron oxides is occurring. This results in the formation of albic materials to the extent that they make up 15 to 85 percent of the volume of the horizon. The albic materials appear as light-colored tongues extending into the horizon between ped surfaces. As the degradation process proceeds, the tongues occupy progressively more of the horizon, until only remnants of the former argillic, kandic, or natric horizon remain.

Generalized Characteristics

1. Horizon has thickness of ≥ 5 cm.
2. Horizon has two distinct parts (eluvial and illuvial), each making up 15-85% of the horizon:
    a. Illuvial part consists of remnants of argillic, kandic, or natric horizon (Bt).
    b. Eluvial part consists of tongues of albic materials (E).

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizons B and E used in combination. Additional suffixes, such as g, n, t, or x, may also be used. Examples include: Bt/E, E/B, and Btn/E.



This glossic horizon is a degrading argillic horizon. Albic material (white) surrounds remnant argillic horizon peds (brown). Scale is in inches.

Back to Glossic Horizon

Gypsic Horizon

Surface or subsoil horizon with an accumulation of gypsum

Concept and Background Information

The gypsic horizon is a horizon with an accumulation of gypsum. It typically is in the subsoil but may be at the surface in some soils. Gypsic horizons form in arid or semiarid environments and are typically associated with gypsiferous parent materials. The secondary gypsum in the horizon commonly results from a combination of illuviation of gypsum into the horizon as well as dissolution and precipitation locally within the horizon. The gypsum typically has moved downward in solution with rainwater and then accumulated at the wetting front. In some soils with a water table, the gypsum may move upward due to capillary rise and accumulate at the surface as the water evaporates. The gypsic horizon generally has no cementation, but the definition includes layers with cementation that is not sufficiently developed to meet the criteria for a petrogypsic horizon. Gypsic horizons are commonly found in arid or semiarid environments where deep leaching and removal of soluble salts (like gypsum) does not occur. The limited precipitation translocates soluble salts to only the depth of moisture penetration, which is typically still within the solum.

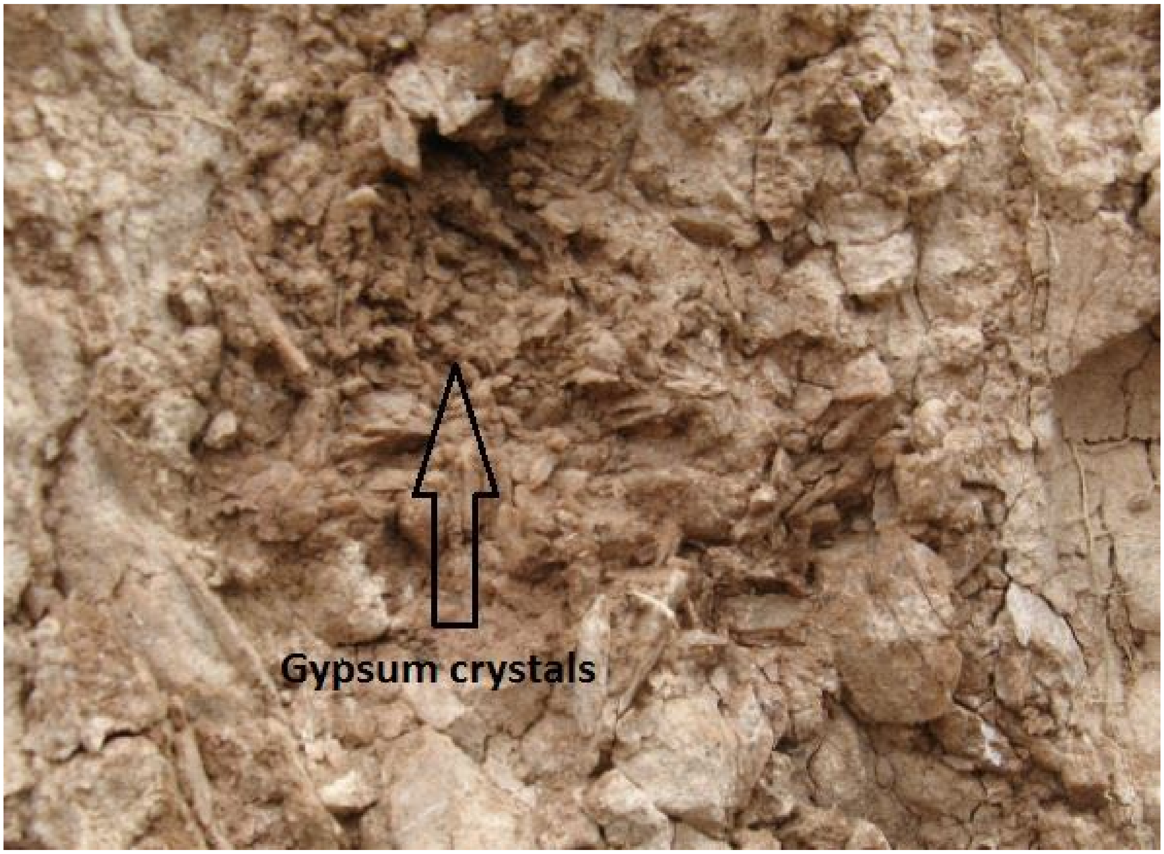
Generalized Characteristics

1. Thickness is ≥ 15 cm.
2. Horizon has ≥ 1% visible secondary gypsum and ≥ 5% gypsum (by weight), and
    a. (Gypsum % wt.) X (thickness in cm) ≥ 150. (For example, if gypsum is 6% and thickness is 20 cm: 6% gypsum X 20 cm = 120; example fails gypsic).
3. Horizon has as no, or minimal, cementation (air-dry fragments disintegrate when submerged in water).

Note: Secondary gypsum may be in forms such as masses or clusters of crystals, pendants beneath rock fragments, or uniformly distributed fine crystals throughout the soil matrix.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B, and sometimes A, combined with suffix y or yy. Additional suffixes, such as k and z, may also be used. Examples include: Ayy, Bky, and By.



A gypsic horizon with nests of gypsum crystals. (Photo courtesy of Dr. David Weindorf)

Back to Gypsic Horizon

Hemic Soil Materials

Organic soil materials that are moderately decomposed

Concept and Background Information

Hemic soil materials are organic soil materials that are moderately decomposed. They are intermediate between the highly decomposed sapric soil materials and the slightly decomposed fibric soil materials. Before rubbing, hemic soil materials have moderate amounts of fibers that can be identified as to their biological origin. The organic material has undergone some physical and chemical alteration, but about 1/3 to 2/3 of the volume is fibers before rubbing. After rubbing however, few intact fibers remain.

A simple field test involves rubbing the material between the fingers (about ten times) to observe the amount of intact fiber that persists after rubbing. Hemic soil materials generally have bulk density of <~0.07-0.18 g/cm^3 and an intermediate water content when saturated (commonly ~450-850%, by weight, compared to oven dry). They are commonly dark grayish brown to dark reddish brown.

Note: For comparison, see the more decomposed sapric and less decomposed fibric soil materials.

Generalized Characteristics

1) Hemic soil materials are intermediate in decomposition between fibric and sapric soil materials.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon O with suffix e (i.e., Oe).

Organic soil materials, including fibric (top), hemic (middle), and sapric (lower) materials. (Photo courtesy of John Kelley)

Return to Hemic Soil Materials

Human-Altered Material

Soil material significantly altered by intentional human activity

Concept and Background Information

Human-altered soil materials have undergone some form of intentional human-induced alteration, including deep plowing to break up root-restrictive subsoil layers, excavation (such as for a gravel pit), and surface compaction in order to puddle water (such as for rice paddies). Although highly altered from their natural state, they have not been transported from another location.

Generalized Characteristics

1) Materials are either:
    a. Tilled to > 50 cm to break up a root-restrictive subsoil layer, or
    b. Occur on a destructional anthropogenic landform (such as a gravel pit), or
    c. Are purposely compacted to puddle water for agricultural purposes,

OR

2) Materials have not been transported and contain evidence of purposeful human alteration.

Note: See 12th edition of the "Keys to Soil Taxonomy" for soil properties to consider as evidence of human alteration.

Common Horizon Nomenclature

There is no specific horizon nomenclature to indicate human-altered material. Some human-altered materials may be indicated with the suffix p or d. Examples include: Ap and Bdg. (Note that the caret symbol prefix [^] is used for human-transported material).

These human-constructed terraces in Nepal are used for growing rice and vegetables. They make up a large-scale anthropogenic landform with both human-altered and human-transported materials. (Photo courtesy of Dr. John Galbraith)

Back to Human-Altered Material

Human-Transported Material

Soil material transported by intentional human activity

Concept and Background Information

Human-transported soil materials are essentially a unique kind of parent material. These materials have been intentionally moved by human activity from a location away from the site where they are now located. Human-transported material is commonly underlain at some depth by a lithologic discontinuity and/or a buried soil horizon from the original soil that formed at the site before deposition of the new material.

Generalized Characteristics

1) Material occurs on a constructional landform (such as a filled-in area).
2) Material contains evidence of purposeful transport by humans from an area outside of the current pedon.

Note: See 12th edition of the "Keys to Soil Taxonomy" for soil properties to consider as evidence of human transport.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes the use of the caret symbol (^) for a prefix in combination with master horizons, such as O, A, B, or C. These may be combined with suffix d, j, u, or w. Examples include: ^Ap, ^Cj, and ^Cdu. Soil material above a layer designated with master symbol M is human-transported.

Profile of a Virginia soil that formed in human-transported material. The upper 52 cm was deposited by truck from nearby sources of fill material and contains scattered broken peds of diagnostic horizons that formed at their original locations. The dark layer at a depth of 60 cm has a high content of wood and coal ash. The lower part of the profile consists of deposits of dredged marine sediments. Scale is in cm. (Photo courtesy of Dr. John Galbraith)

Identifiable Secondary Carbonates

Visible calcium carbonate that has been precipitated in the soil

Concept and Background Information

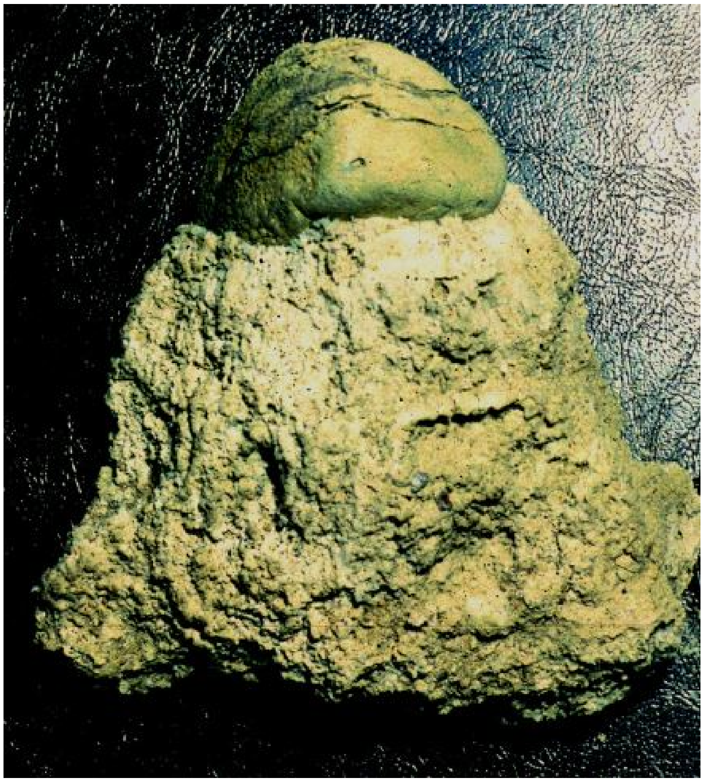
Identifiable secondary carbonates are forms of calcium carbonate in the soil that are the result of pedogenic processes. The source of the carbonates may have been in the original parent material, or it may have been introduced from outside the soil profile through dust-fall or the lateral movement of water in the subsoil. Regardless of the source, however, the carbonates must have been translocated and precipitated within the soil to qualify as identifiable secondary carbonates. In addition, the feature must be thick enough to be visible even when moist, generally about 1 mm or more in size. Forms include masses, nodules, concretions, coatings on peds or in pores, filaments in the soil matrix, and pendants on the undersides of rock fragments. Some horizons are completely engulfed in calcium carbonates, and their light color is determined largely by the calcium carbonates. These are within the concept of identifiable secondary carbonates.

Generalized Characteristics

1) Carbonates are pedogenic in nature.
2) Carbonates are thick enough to be visible when moist.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B, or sometimes A or C, and the use of suffix k or kk alone or in combination with other suffixes, such as n, y, or z. Examples include: Ak, Bkny, and Bkk. In addition, the description of the horizon includes information about the kind and amount of carbonates present.



A pendant of secondary calcium carbonate coating the underside of a rock fragment.

Back to Identifiable Secondary Carbonates

Profile of a Calciustoll with identifiable secondary carbonates (white bodies) below a depth of about 28 inches. Scale is in feet.

Back to Identifiable Secondary Carbonates

Interfingering of Albic Materials

Narrow penetrations of light-colored, leached material into a subsoil horizon

Concept and Background Information

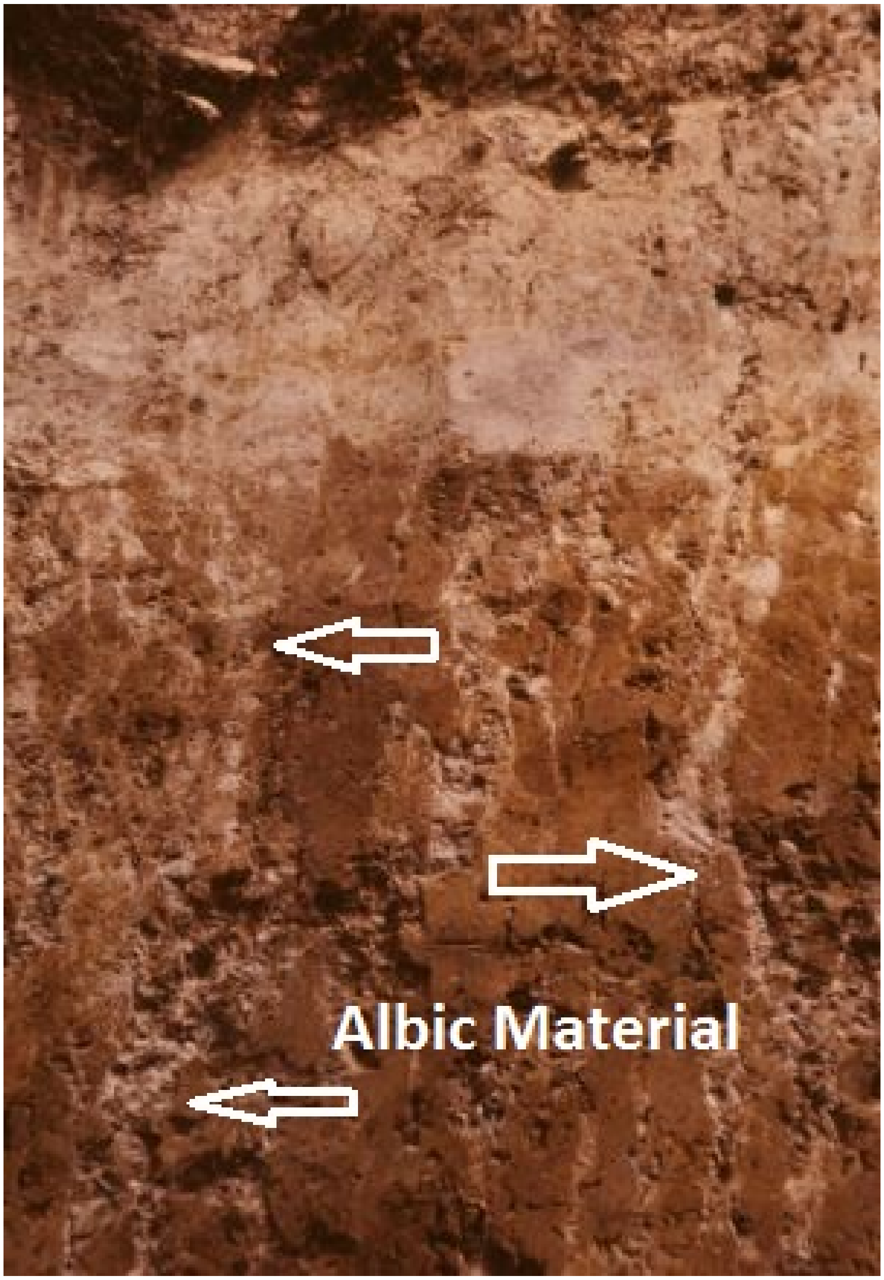
Interfingering of albic materials is a soil feature consisting of thin penetrations of albic materials (light-colored, leached soil material) extending 5 cm or more into a clay-enriched horizon. The penetrations are along vertical, and to a lesser degree horizontal, ped surfaces. There may or may not be a continuous albic horizon above. The albic materials make up less than 15% of the horizon. They are mostly light gray when moist and nearly white when dry. The color is controlled by the primary sand and silt particles making up the feature.

Generalized Characteristics

1) Feature consists of light-colored, leached material (albic materials).
2) Albic materials extend $\geq$ 5 cm into a clay-enriched subsoil layer.
3) Penetrations are $\geq$ 2 mm thick.
4) Albic materials constitute < 15% of the volume of the horizon.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizons B and E used in combination. In some cases, where the amount of albic materials is quite low, the horizon may only be designated as a B and the nature of the albic material penetrations described in the horizon description. Suffixes such as g, n, t, or x may also be used. Examples include: B/E, Btn, and Btx.



Interfingering of albic materials (white) into an argillic horizon (brown).

Back to Interfingering of Albic Materials

Kandic Horizon

Subsoil horizon with a low nutrient-holding capacity and significantly more clay than the overlying surface layer

Concept and Background Information

The kandic horizon is a subsoil horizon that has a significantly higher content of clay than the horizons above and has a low nutrient-holding capacity. The difference in clay content may be the result of eluviation/illuviation processes, but this is not a requirement for the kandic horizon (as it is for the argillic and natric horizons). Other processes leading to the increase in clay content from the surface layer to the kandic horizon include the chemical dissolution of clay in the surface layers, the selective erosion of the finer (clay) particles from the surface layers, and the chemical formation of clay within the kandic horizon.

The clay minerals making up the kandic horizon are generally referred to as low-activity clays due to their low nutrient-holding capacity (or low cation-exchange capacity). Soils with kandic horizons tend to have low native fertility. The presence of a kandic horizon generally suggests that the soil has undergone a high degree of weathering in a warm, humid climate.

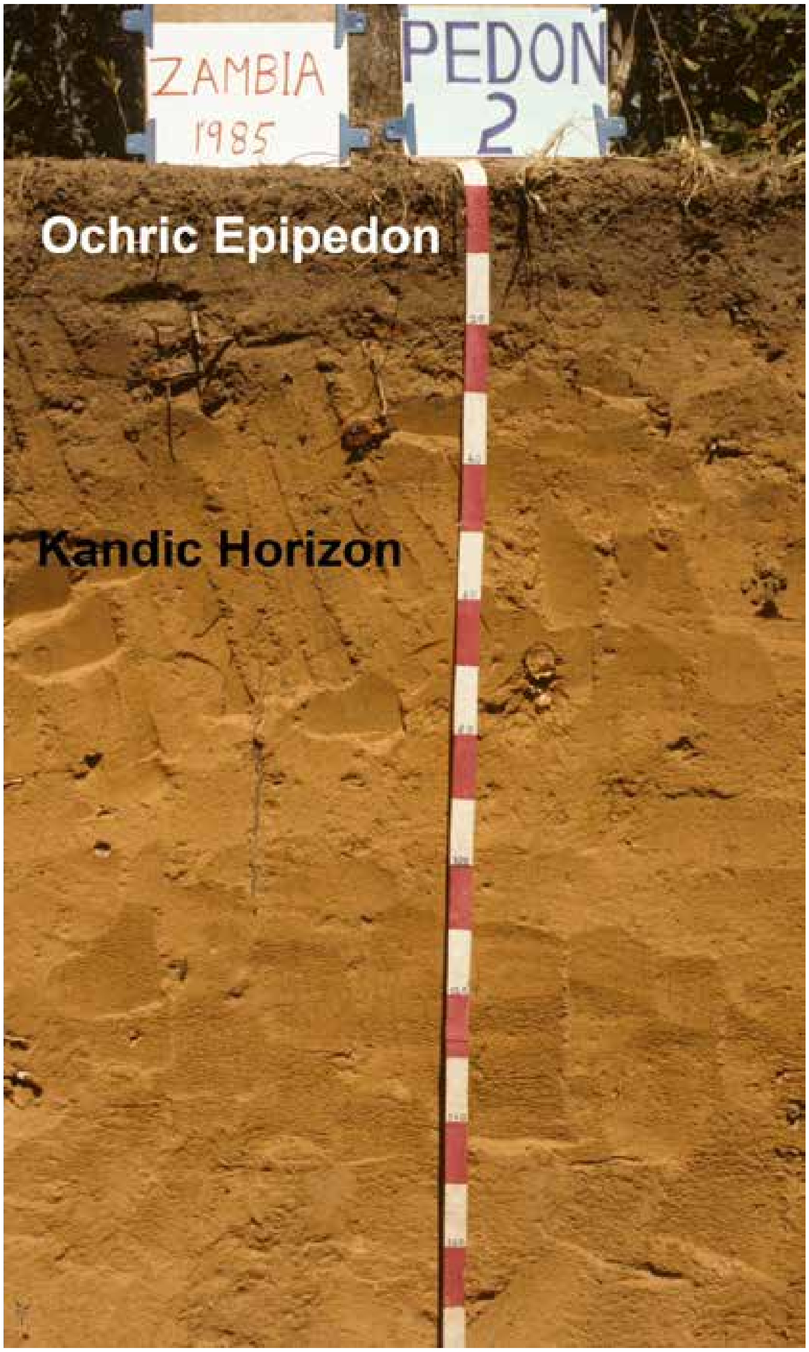
Generalized Characteristics

1) Horizon underlies a coarser textured surface layer $\geq$ 18 cm thick.
2) Horizon is $\geq$ 30 cm thick.
3) Clay percent increases significantly within a vertical distance of $\leq$ 15 cm. (Minimum required increase ranges from 4 to 8 percent, depending on the clay content of the overlying layer.)
4) Horizon begins generally at a depth of $\leq$ 125 cm. (See 12th edition of the “Keys to Soil Taxonomy” for exceptions.)
5) Texture is loamy or clayey.
6) CEC (cation-exchange capacity) is $\leq$ 16 and ECEC (effective cation-exchange capacity) is < 12 (cmol$^+$ per kg clay).
7) Horizon is not alluvial in nature (there is no fine stratification and organic carbon content decreases regularly with increasing depth).

Note: CEC or ECEC sometimes is reported for the fine-earth fraction rather than just the clay fraction. To convert to clay basis:
CEC $_{(fine\ earth)}$ X 100 / % clay.
For example, 12 $_{(cec\ fine\ earth)}$ X 100 / 30% clay = CEC 40 cmol$^+$ kg clay.

Common Horizon Nomenclature

There is no horizon nomenclature to designate the presence of the low-activity clays that characterize the kandic horizon. Commonly used horizon nomenclature includes master horizon B, often in combination with suffixes such as g, t, or v. Examples include: Bt, Btv, and Btg.



Profile of a soil in Zambia that has a dark brown ochric epipedon about 20 cm thick. The ochric epipedon is underlain by a yellowish red kandic horizon that extends below the base of the photo. Scale colors are in 10-cm increments.

Back to Kandic Horizon

Lamellae

Two or more thin layers with accumulation of illuvial clay

Concept and Background Information

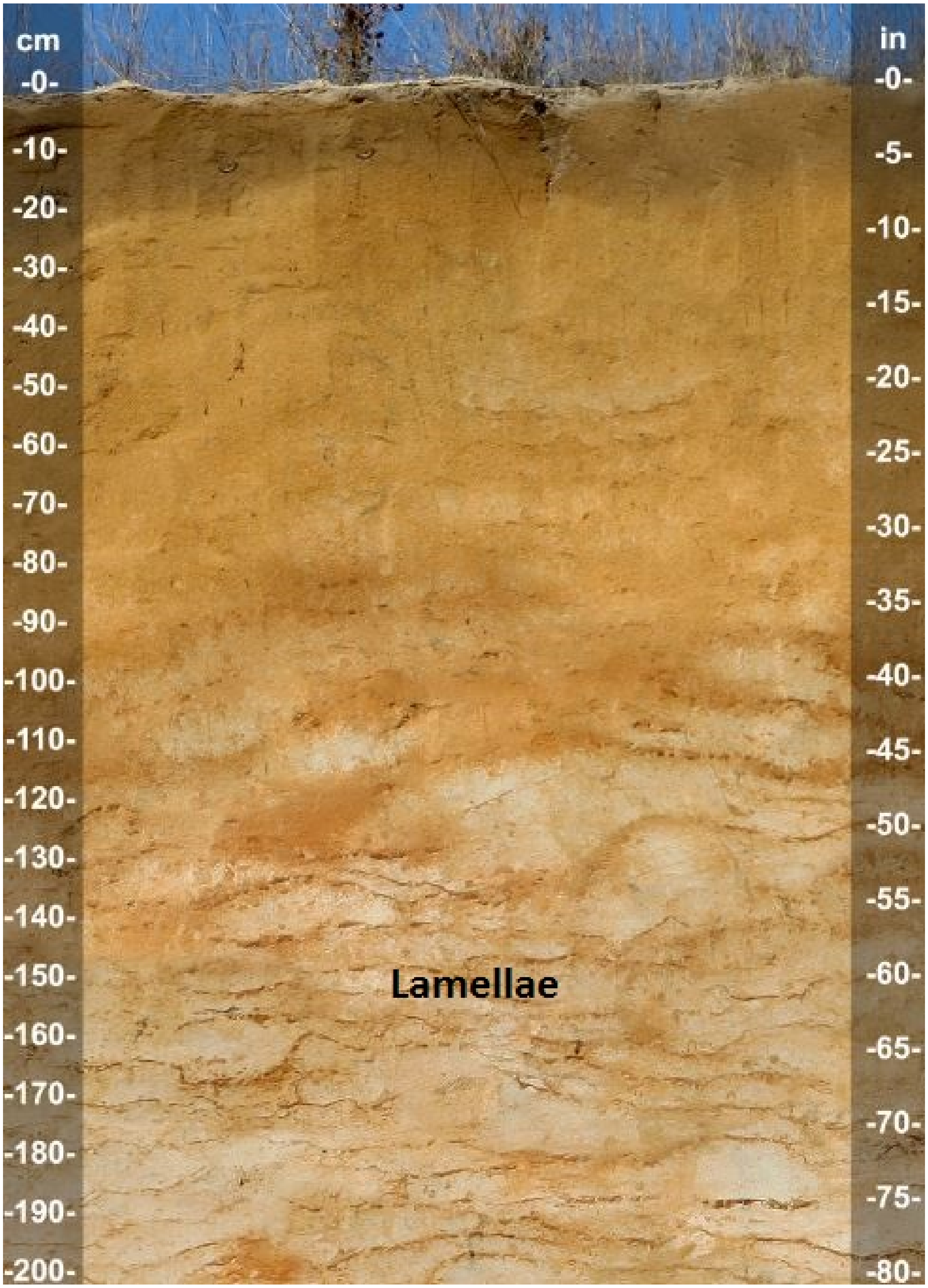
Lamellae consist of two or more thin layers with accumulation of illuvial clay. Each individual lamella is associated with an overlying eluvial layer containing less clay than the lamella below it. Each lamella is < 7.5 cm thick and commonly just a few millimeters thick. Lamellae form in unconsolidated materials at least 50 cm thick. Lamellae that collectively total ≥ 15 cm qualify for either a cambic horizon (if they are very fine sand, loamy very fine sand, or finer) or, if they are at least 0.5 cm thick and have a sufficiently large increase in clay content, an argillic horizon.

Generalized Characteristics

1) Lamellae contain illuvial clay.
2) Thickness of individual lamella is < 7.5 cm.
3) Lamellae occur in vertical series of two or more.
4) Each lamella has an eluvial layer above it.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes the combination of master horizons E and B and the word “and.” Examples include: “E and Bt” and “E and B.”



Profile of a soil that has an argillic horizon composed of lamellae. (Photo courtesy of John Kelley)

Back to Lamellae

Lithic Contact

Contact between unconsolidated soil material and the underlying root-restrictive hard bedrock

Concept and Background Information

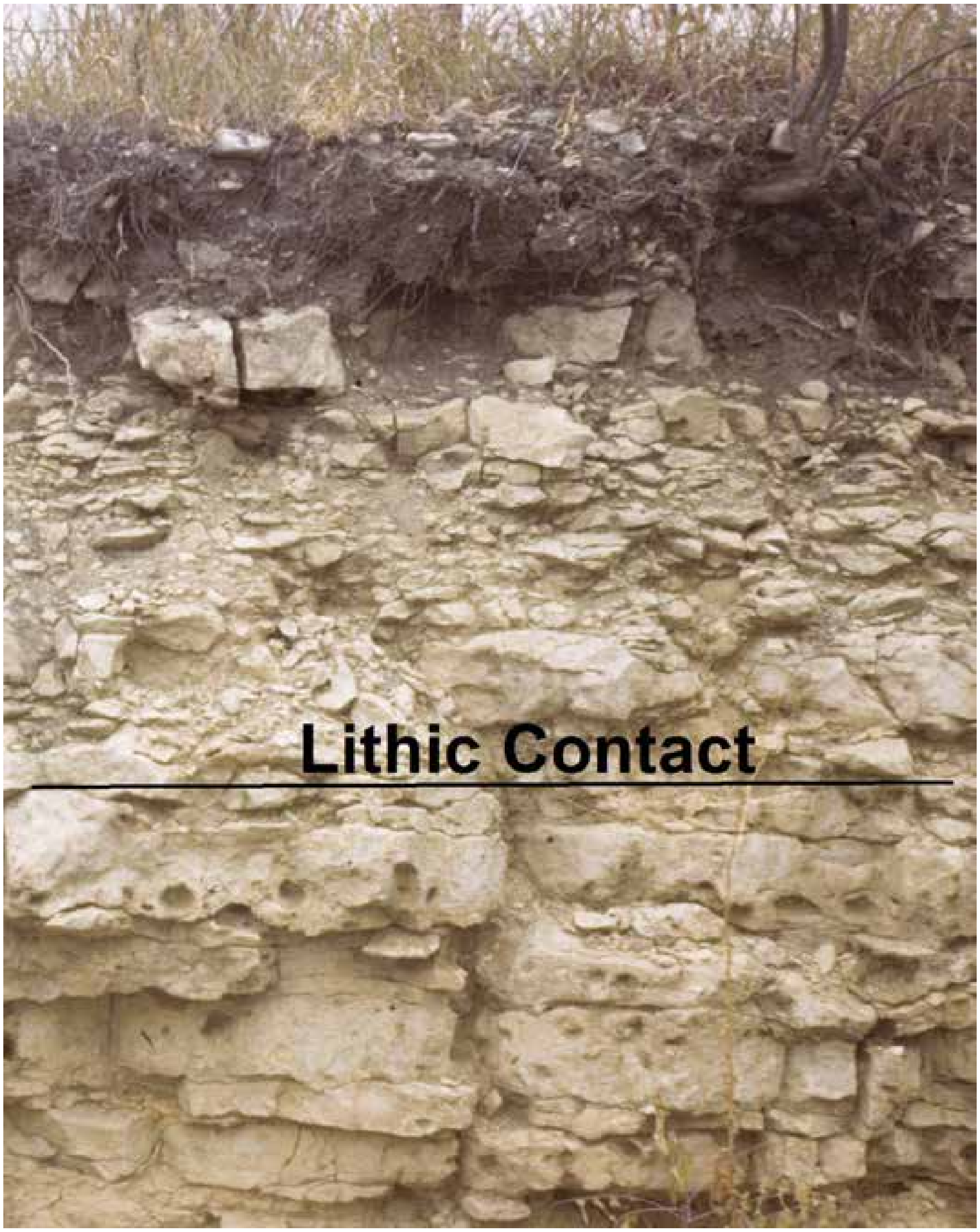
The lithic contact is the boundary between unconsolidated soil material and the underlying root-restrictive hard bedrock. Any cracks that allow penetration by roots are spaced more than 10 cm apart. The underlying bedrock is hard enough to make hand digging impractical, if not impossible (the cementation class is strongly cemented to indurated).

Generalized Characteristics

1) The contact is to underlying hard bedrock.
2) Cementation class is strongly cemented to indurated.
3) Spaces where roots can penetrate are more than 10 cm apart.
4) Underlying material is not a diagnostic horizon (such as a duripan or a petrocalcic horizon).

Common Horizon Nomenclature

A lithic contact is identified at the boundary between soil and continuous hard bedrock, such as the upper boundary of an R horizon*. Note: A lithic contact is NOT recognized at the upper boundary of a pedogenically cemented diagnostic horizon, such as a petrocalcic horizon or a duripan*.



Soil profile with a lithic contact over hard limestone. Note that the upper part of the profile consists of soil and loose rock fragments. The lithic contact is at the top of the continuous bedrock layer, which comprises about the lower third of the photo.

Return to Lithic Contact

n Value

A value that describes the ability of a saturated soil to support a load

Concept and Background Information

The *n* value describes the ability of a saturated soil to support a load, such as grazing cattle or small machinery. It considers the percentage of water held under field conditions as well as percentages of silt, sand, clay, and organic matter in the soil (see the 12th edition of the "Keys to Soil Taxonomy" for the formula used). For soil classification purposes, a critical *n* value of 0.7 is used. A simple field test involves squeezing a fist-full of soil. If the soil flows between the fingers but with difficulty (i.e., slightly fluid), the n value is likely between 0.7 and 1.0. If the soil flows easily (i.e., moderately fluid or very fluid), it is greater than 1.0. If no soil flows between the fingers (non-fluid), it is less than 0.7.

Common Horizon Nomenclature

There is no horizon nomenclature to infer the *n* value. Where appropriate, the fluidity class is mentioned in the description of the horizon and commonly used horizon nomenclature includes master horizon C, often in combination with suffix g or se, such as Cg and Cseg.

This moderately fluid saturated soil flows fairly easily between the fingers when squeezed, indicating it has an *n* value greater than 1.0.

Return to *n* Value

Natric Horizon

Subsoil horizon with an illuvial accumulation of clay along and high levels of sodium

Concept and Background Information

The natric horizon is a subsoil horizon that, in addition to having all the characteristics of an argillic horizon (i.e., significant clay accumulation), has high levels of sodium. In effect, it is a special kind of argillic horizon. The high amount of sodium causes clay to disperse, thus enhancing the movement of clay into the subsoil. Natric horizons commonly have columnar or prismatic structure, and they may also have light-colored uncoated sand or silt grains on ped surfaces, especially on the upper surface of the columns. Soils with a high amount of sodium (and no other salts) tend to have rather high pH (> 9.0 in some cases). They may also have poor physical structure, which impedes the movement of air and water through the soil.

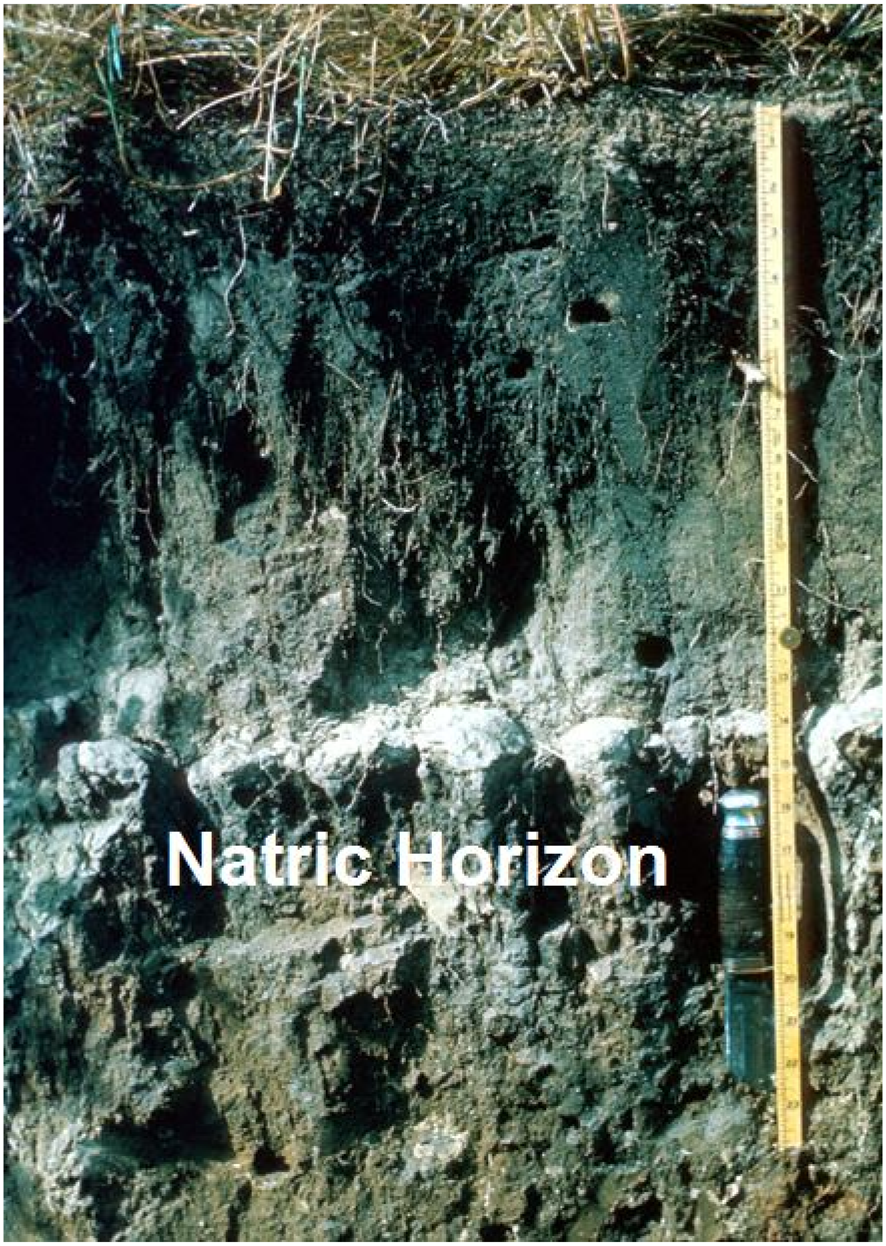
Generalized Characteristics

(Note: Items 1, 2, and 3 are shared with the argillic horizon.)

1) Thickness is ≥ 7.5 cm (≥ 15 cm if horizon is sandy or composed of lamellae).
2) There is evidence of clay illuviation, *either*
    a. Field evidence (clay films in pores or on peds or clay bridging of sand grains), *or*
    b. Laboratory evidence (oriented clay in thin section or significantly more fine clay [as fraction of total clay] in the Btn horizon as compared to the eluvial layer above).
3) Clay percent increases significantly within a vertical distance of ≤ 30 cm. (Minimum required increase ranges from 3 to 8 percent, depending on the clay content of the eluvial layer.)
4) Structure is columnar or prismatic, or it is blocky and there are also light-colored uncoated sand or silt grains extending > 2.5 cm into the horizon.
5) Within 40 cm of the top of the natric horizon, horizon has *either:*
    a. And exchangeable sodium percentage (ESP) ≥ 15% or a sodium adsorption ratio (SAR) ≥ 13, *or*
    b. If ESP ≥ 15 or SAR is ≥ 13, anywhere within 200 cm of the soil surface, more exchangeable Mg + Na than Ca + extractable acidity.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B, along with combined suffixes t and n. (These may be in combination with other suffixes such as g, ss, y, or z). Examples include: Btn, Btny, and Btnz.



This natric horizon (lower half of profile) has characteristic columnar structure and light-colored silt coatings on the top surface of the peds.

Back to Natric Horizon

Oxic Horizon

Subsoil horizon that is extremely weathered and has a very low nutrient-holding capacity

Concept and Background Information

The oxic horizon has undergone extreme weathering. As a result, it has few primary weatherable minerals remaining. It is dominated by quartz and other highly resistant minerals in the sand and silt fraction. The clay fraction is dominated by clay minerals such as kaolinite and sesquioxides (iron- and aluminum-oxides) that have a very low nutrient-holding ability (i.e., low activity clays). The combination of a low ability to hold existing nutrients and little capacity to supply new nutrients through weathering of primary minerals results in very low native fertility. Biocycling of nutrients between the soil, microbes, and plant tissues is critical to sustaining adequate fertility and growth of native vegetation. Cultivated areas require substantial and continued application of fertilizers, especially phosphorous because it tends to become “fixed” in the soil and unavailable to plant roots. Oxic horizons commonly have granular or fine subangular blocky structure, which causes them to be friable and very porous.

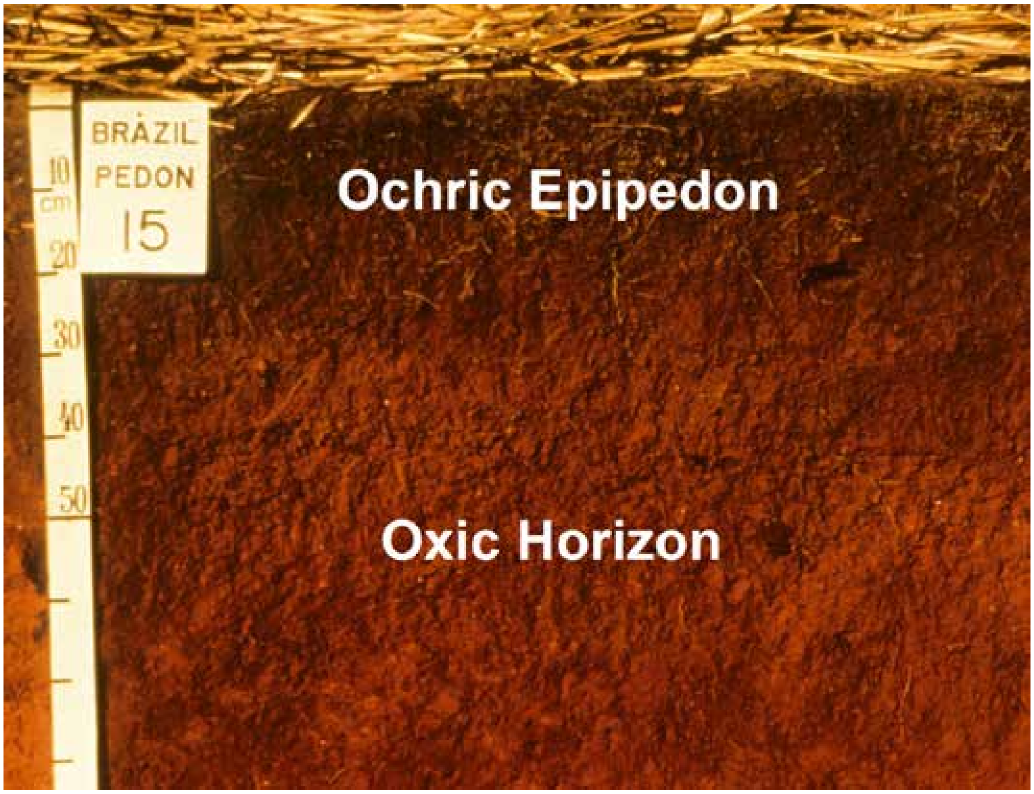
Generalized Characteristics

1) Thickness is $\geq$ 30 cm.
2) Texture is loamy or clayey.
3) Horizon has < 10% weatherable minerals in the fine and very fine sand fraction (i.e., 0.05 - 0.2 mm).
4) Horizon has < 5% rock structure.
5) Clay percent increases little between the surface layer and the oxic horizon. (Maximum permitted increase within 15 cm ranges from 3 to 7 percent, depending on the clay content of the overlying layer).
6) CEC (cation-exchange capacity) is $\leq$ 16 and ECEC (effective cation-exchange capacity) is $\leq$ 12 (cmol$^+$ per kg clay).

Note: CEC/ECEC may be reported for the fine-earth fraction rather than just clay. To convert to clay basis: CEC $_{(fine\ earth)}$ X 100 / % clay. For example, 12 $_{(cec\ fine\ earth)}$ X 100 / 30% clay = CEC 40 cmol$^+$ kg clay.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B and suffix o, which are combined with suffix g, t, or, v in some cases. Examples include: Bo, Bto, and Bov.



Profile of a soil in Brazil that has a highly weathered clayey oxic horizon with a fine grade of structure below a darkened ochric epipedon. The oxic horizon begins at a depth of about 25 cm and extends below the base of the photo.

Back to Oxic Horizon

Paralithic Contact

Contact between unconsolidated soil material and the underlying root-restrictive soft bedrock

Concept and Background Information

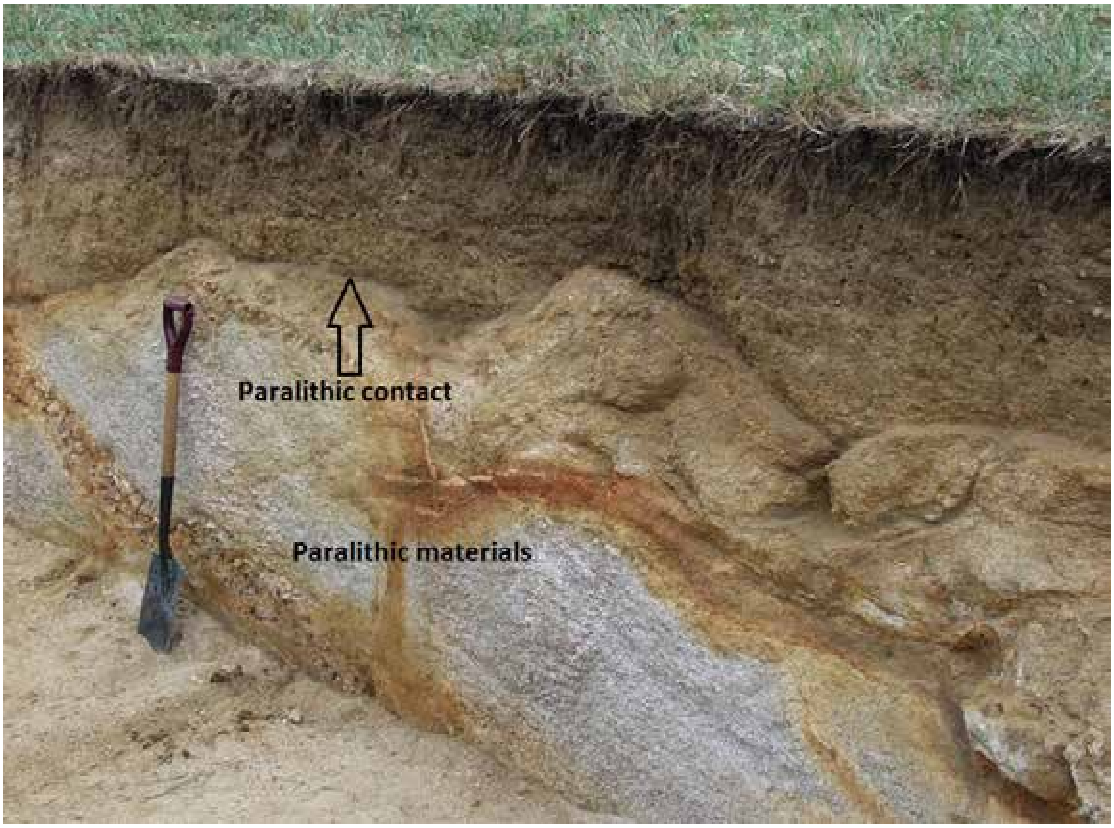
The paralithic contact is the boundary between unconsolidated soil material and the underlying root-restrictive soft bedrock (paralithic materials). Cracks that allow penetration by roots are spaced more than 10 cm apart. The underlying bedrock is soft enough to make hand digging possible, although it may be difficult (the cementation class is extremely weak to moderate). Because the material is cemented, air-dry fragments do not slake in water. The material underlying the paralithic contact commonly is weathered bedrock or bedrock that may never have been strongly consolidated.

Generalized Characteristics

1) The contact is to underlying soft bedrock.
2) The cementation class is extremely weak to moderate.
3) Spaces where roots can penetrate are more than 10 cm apart.
4) Underlying material is not a diagnostic horizon (such as a duripan or a petrocalcic horizon).

Common Horizon Nomenclature

A paralithic contact is identified at the boundary between soil and continuous soft bedrock (indicated by master horizon C and suffix r), i.e., the upper boundary of a Cr horizon.



This soil has an abrupt way boundary at the paralithic contact. The material below the contact is relatively soft, weathered bedrock that can be dug with a spade. (Photo courtesy of John Kelley)

Return to Paralithic Contact

Permafrost

Frozen layer within the soil

Concept and Background Information

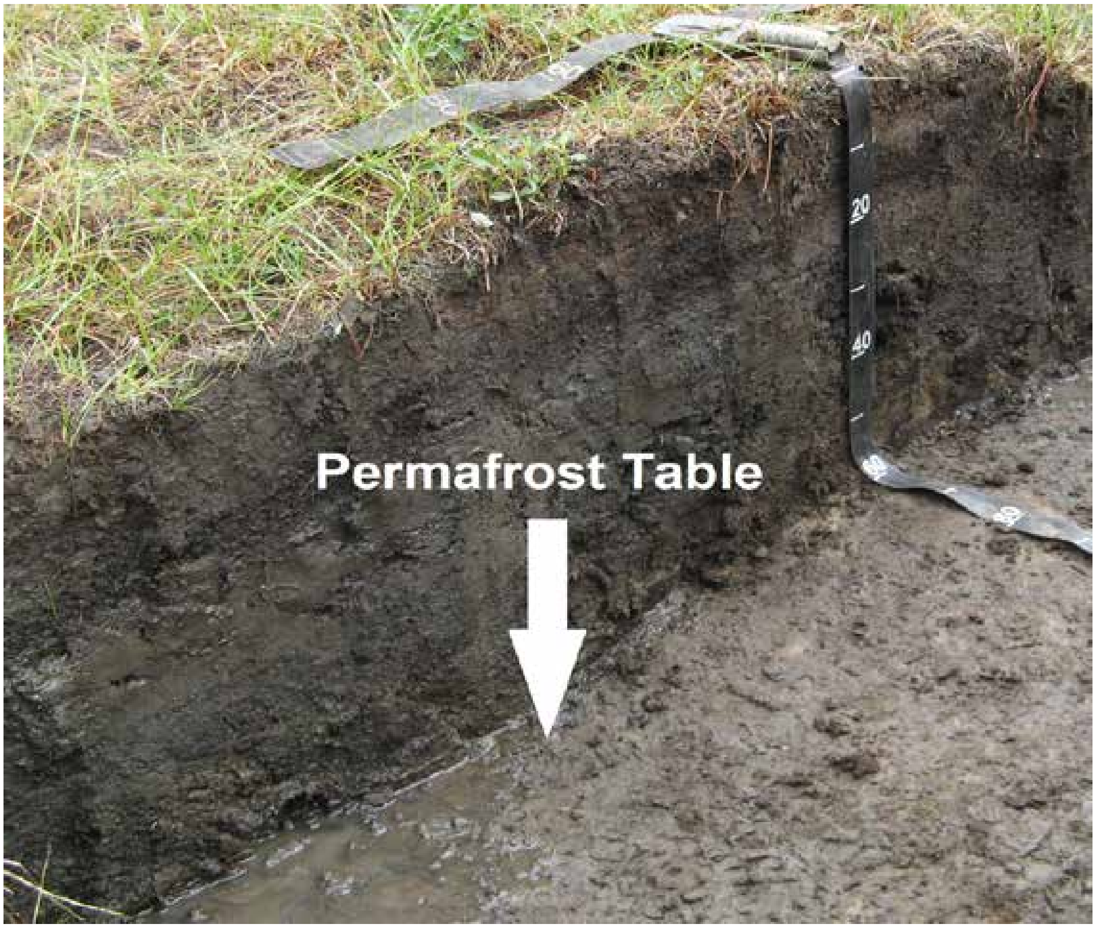
A frozen layer with a temperature that has remained below 0 °C for 2 or more consecutive years is considered permafrost. It may be impregnated with ice, or it may be dry. Layers above the permafrost freeze and thaw annually.

Generalized Characteristics

1) Layer has temperature of < 0 °C for 2 or more consecutive years.

Common Horizon Nomenclature

Commonly, soil horizons with permafrost are identified through the use of either suffix f or ff (for moist or dry permafrost, respectively). Additional suffixes commonly used with permafrost layers are a, e, and or g. Master horizons are mostly indicated as O or C, but A and B are also used. Examples include: Cff, Oaf, and Bfg.



A soil in Alaska that is permanently frozen below a depth of about 60 cm. Scale is in cm. (Photo courtesy of Dr. David Weindorff)

Return to Permafrost

Perudic Moisture Regime

Regime characteristic of areas where precipitation exceeds evapotranspiration every month

Concept and Background Information

The perudic soil moisture regime occurs in areas with very high rainfall. Precipitation exceeds evapotranspiration by plants in every month. The perudic moisture regime is a special type of udic regime. Areas of soils with a perudic regime are generally rather small. Most commonly, they occur at high elevations in mountains with very high precipitation.

See the generalized map of soil moisture regime regions in the continental United States. (Note: The perudic areas are too small to indicate at this map scale.)

Generalized Characteristics

1) Precipitation exceeds evapotranspiration by plants in every month.

Common Horizon Nomenclature

There is no horizon nomenclature indicating that a soil has a perudic moisture regime.

Petrocalcic Horizon

Root-restrictive subsoil horizon that is cemented by calcium carbonate

Concept and Background Information

The petrocalcic horizon is a root-restrictive subsoil horizon that is cemented by calcium carbonate. Lateral continuity is such that spaces where roots can penetrate are more than 10 cm apart. This horizon is essentially an advanced-stage calcic horizon where so much secondary calcium carbonate has accumulated in the layer that the pores have become plugged and cemented. Air-dry fragments do not slake in water but will slake in HCL, thus confirming calcium carbonate as the cementing agent. The carbonates may have been deposited (e.g., as dust) from outside the profile, or, in naturally calcareous parent materials, the carbonates may be dissolved and reprecipitated locally within the horizon. Petrocalcic horizons are commonly found in arid or semiarid environments where deep leaching and removal of soluble salts like calcium carbonate do not take place.

Generalized Characteristics

1) Horizon is cemented by carbonates to such an extent that spaces where roots can penetrate are more than 10 cm apart.
2) Horizon is $\geq$ 10 cm thick (or $\geq$ 1 cm thick, if it is a laminar cap resting on bedrock).

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B combined with suffixes kk and m. In addition, suffixes n, q, y, and z are sometimes used. Examples include: Bkkm, Bkkzm, and Bkkym.

Old alluvial gravel cemented in a matrix of illuvial calcium carbonate (white) form a very strongly cemented petrocalcic horizon (in a soil in the United Arab Emirates). (Photo courtesy of Dr. Craig Ditzler)

Back to Petrocalcic Horizon

This New Mexico soil has a petrocalcic horizon below a depth of about 80 cm. Scale is in cm.

Back to Petrocalcic Horizon

Cross-section of the upper part of a petrocalcic horizon with a laminar cap. The penciled numbers are the ages of various parts of the layer. Scale is in inches.

Back to Petrocalcic Horizon

Petroferric Contact

Boundary between unconsolidated soil and a layer cemented with iron

Concept and Background Information

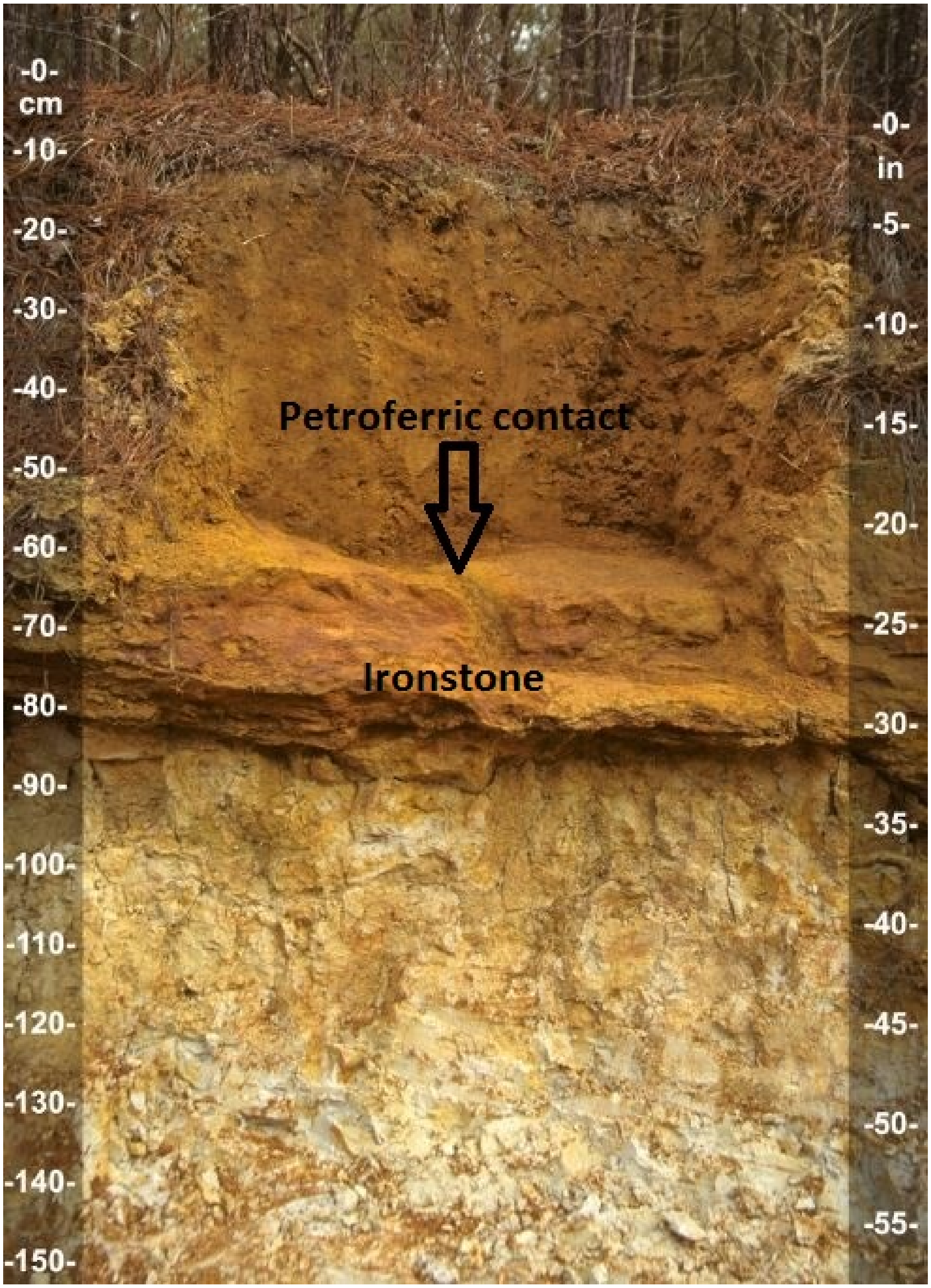
The petroferric contact is the boundary between unconsolidated soil material and a root-restrictive subsoil feature that is cemented primarily by iron (ironstone). Organic matter as part of the cementing agent is either absent or in small amounts (this distinguishes the cemented layer below the petroferric contact from the placic horizon). The petroferric contact is generally recognized in some tropical and subtropical areas where layers of ironstone have formed in the soil as sesquioxides accumulated. The ironstone is generally more or less horizontal but may have a wavy or irregular boundary. It is commonly only a few centimeters thick but can be a few meters thick.

Generalized Characteristics

1) The contact is to an iron-cemented layer (ironstone).
2) Spaces that roots can penetrate are more than 10 cm apart.
3) Thickness of the ironstone below the contact generally ranges from a few centimeters to a few meters.

Common Horizon Nomenclature

A petroferric contact is identified at the boundary between soil and a layer or thin sheet of continuous ironstone. In some cases, especially if the ironstone sheet is less than 1 cm thick, the contact may only be described within the text of the horizon description and not as a distinct layer.



This soil has a petroferric contact at the upper boundary between the unconsolidated soil above and the indurated ironstone sheet below. The soil material below the ironstone is unconsolidated. (Photo courtesy of John Kelley)

Back to Petroferric Contact

Petrogypsic Horizon

Root-restrictive subsoil horizon that is cemented by gypsum

Concept and Background Information

The petrogypsic horizon is a root-restrictive subsoil horizon that is cemented by gypsum. Lateral continuity is such that spaces where roots can penetrate are more than 10 cm apart. The horizon is essentially an advanced-stage gypsic horizon where so much secondary gypsum has accumulated in the layer that the pores have become plugged and cemented. Air-dry fragments do not readily slake in water. Commonly, the gypsum was naturally occurring in the parent materials, where it was dissolved and reprecipitated locally within the horizon. Petrogypsic horizons are commonly found in arid or semiarid environments where deep leaching and removal of soluble salts like gypsum does not take place.

Generalized Characteristics

1) Horizon is cemented by gypsum to such an extent that spaces where roots can penetrate are more than 10 cm apart.
2) Thickness is $\geq$ 5 mm.
3) Gypsum content (by weight) is $\geq$ 40%.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B combined with suffixes yy and m. In addition, suffixes k and z may be used. Examples include: Byym, Byykm, and Byyzm.

Soil landscape and close-up of a petrogypsic horizon (inset) in the United Arab Emirates. (Photo courtesy of John Kelley)

Back to Petrogypsic Horizon

Placic Horizon

Root-restrictive, dark-colored subsoil horizon that is cemented by iron and organic matter

Concept and Background Information

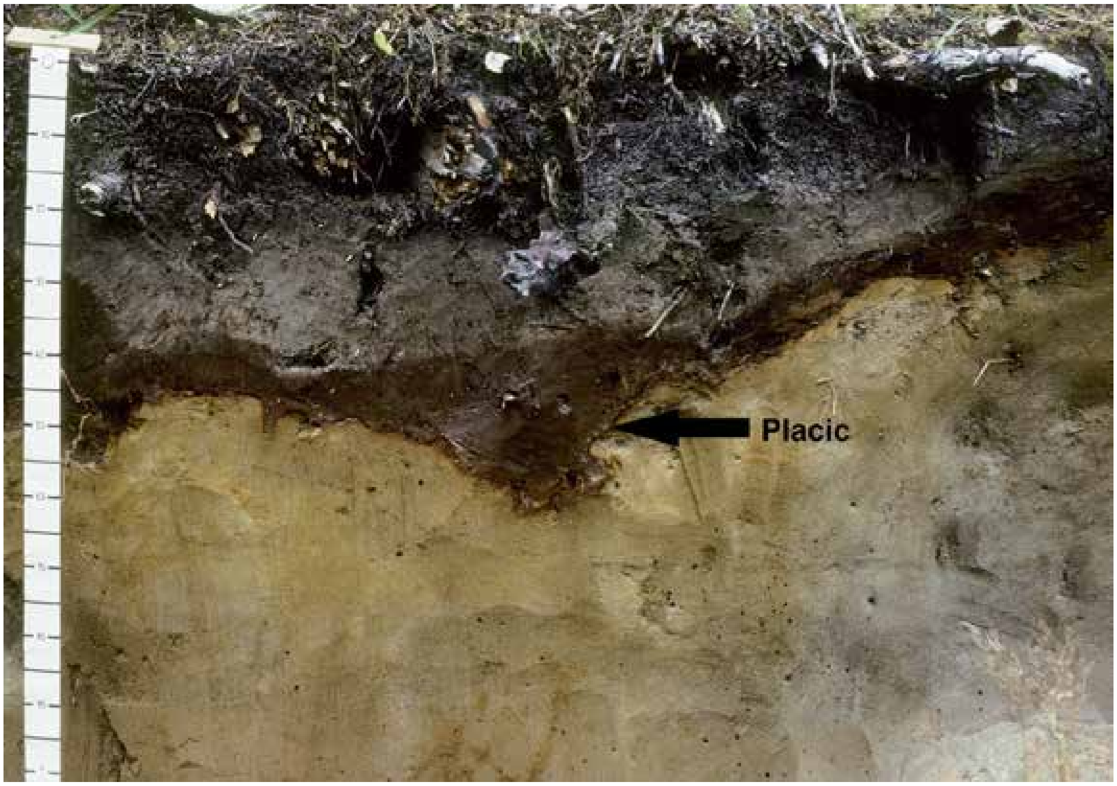
The placic horizon is a root-restrictive subsoil horizon that is cemented by iron and organic matter. Lateral continuity is such that spaces where roots can penetrate are more than 10 cm apart. The placic horizon is dark in color, ranging from black to dark red. It is generally thin, commonly 2 to 10 mm in thickness, and is mostly found within 50 cm of the soil surface. It generally occurs in cool, moist climates with low evapotranspiration rates but is also known to occur in warm, humid areas. It is frequently associated with stratified deposits, such as ash layers.

Generalized Characteristics

1) Horizon is cemented by iron and organic matter to such an extent that spaces where roots can penetrate are more than 10 cm apart.
2) Horizon is $\geq$ 1 mm thick (where it is associated with spodic materials, is it no more than 25 mm thick).

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B combined with suffixes s and m and sometimes h. Examples include: Bsm and Bhsm.



Profile of a soil in New Zealand (specifically a Placorthod) that has a thin, cemented placic horizon just a few mm thick at the wavy contact between the dark yellowish brown material above and the reddish yellow material below. Scale is in cm.

Return to Placic Horizon

Plinthite

Subsoil feature consisting of a firm iron-oxide-rich mass that irreversibly hardens after exposure to repeated wet-dry cycles

Concept and Background Information

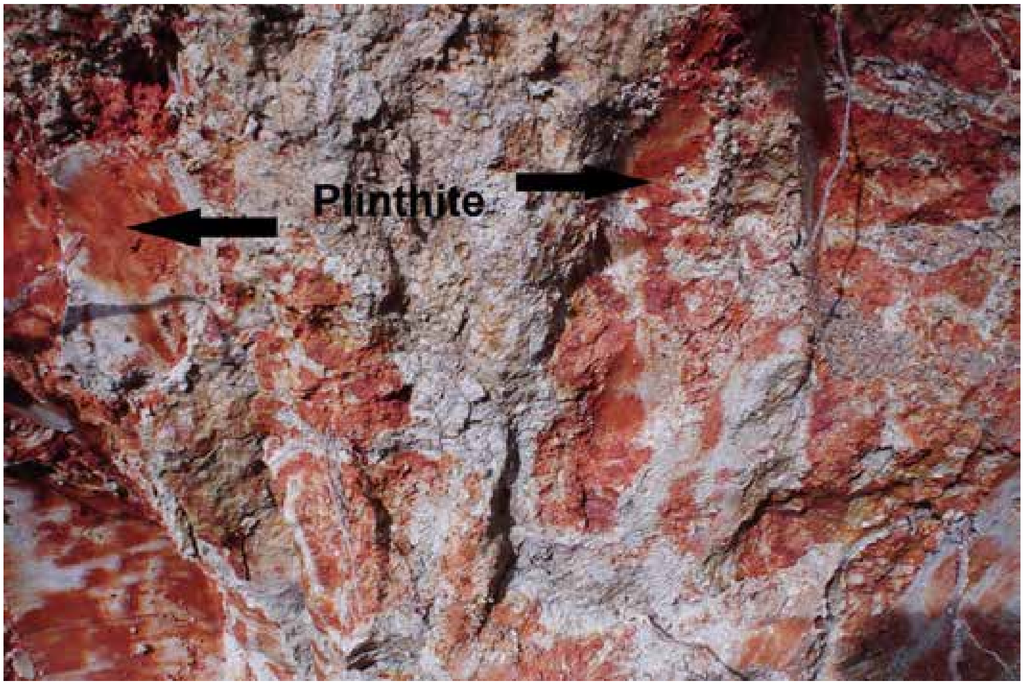
Plinthite is a reddish firm mass consisting of an accumulation of iron-oxide in association with clay, quartz, and other minerals. It has little or no organic matter. It can occur as individual masses or as a continuous phase where it forms platy, polygonal, or reticulate patterns in the soil. Plinthite is a discrete body that can be removed intact from the soil. It will irreversibly harden to form ironstone if it is subjected to repeated wet-dry cycles, particularly after exposure to heat and sunlight (such as in a road cut or gully sidewall). Once hardened, it is ironstone and no longer considered plinthite.

Generalized Characteristics

1) Feature is a firm or very firm mass with an accumulation of iron and little or no organic matter.
2) Mass will harden irreversibly after repeating wetting and drying upon exposure.
3) Feature generally has a dark red color.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B combined with suffix v and generally t. Additional suffixes c, g, and o may also be used. Examples include: Btv, Bov, and Btgv.



Plinthite (firm, dark red concentrations) in a soil near College Station, Texas. (Photo courtesy Dr. David Weindorf)

Bricks made by hand from dried, plinthite-rich soil material (India).

Back to Plinthite

Redoximorphic Features

Morphological features caused by wetness that are characterized by distinctive reddish and grayish color patterns

Concept and Background

The distinctive color patterns associated with redoximorphic features form as a result of change in soil color due to the loss or gain of pigment. This change of pigment is due to the saturation of the soil with water to the extent that most oxygen is depleted from it. In this anaerobic environment, microbes must rely on elements other than oxygen to carry out their metabolism. In so doing, these elements are reduced (i.e., they gain an electron). Two important elements involved in this process are manganese and iron. When they are converted from their oxidized state to their reduced state, they become mobile and move in solution within the soil. As a result, manganese and iron ions tend to move along a gradient from areas within the soil that are void of oxygen to areas where oxygen is present (such as ped faces and pores). In the oxygenated areas, these ions return to their oxidized state (i.e., they lose an electron) and are immobilized. This process is marked by the formation of redoximorphic features in the soil. Areas depleted of iron and manganese tend to be gray in color, forming *redox depletions*, while areas where the iron and manganese have accumulated are redder (or black for manganese), forming *redox concentrations*.

For more information see Aquic Conditions.

Common Horizon Nomenclature

Other than the suffix g (for strong gleying), there is no horizon nomenclature that specifically indicates the presence of redoximorphic features. Redoximophic features are identified as either concentrations or depletions within the horizon description.

Salic Horizon

Saline horizon with an accumulation of salts

Concept and Background Information

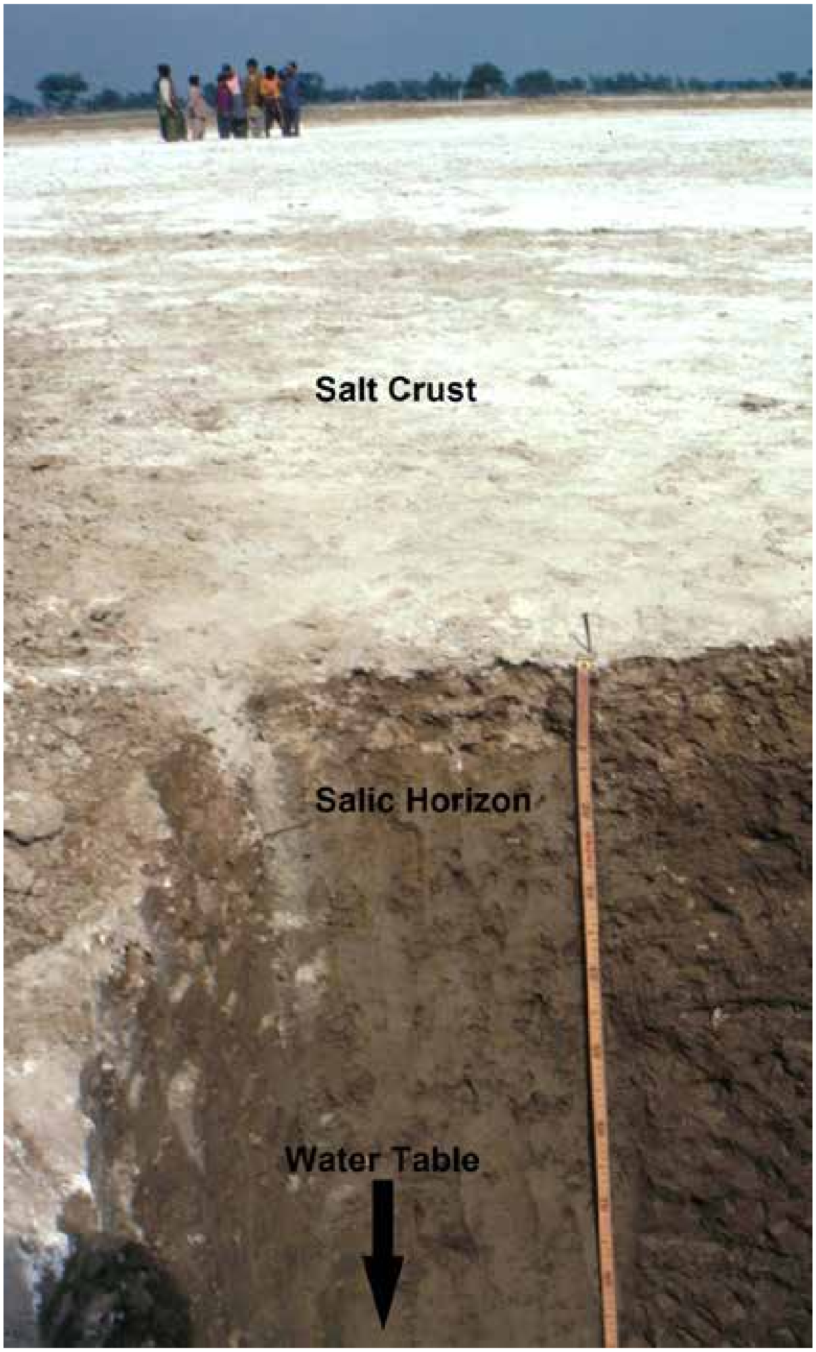
The salic horizon is a saline horizon in which salts more soluble than gypsum have accumulated. Halite is one of the more common salts in salic horizons, but other salts also occur. The salic horizon may be either in the subsoil (where precipitation leaches salts downward) or at the surface (where salts are wicking upward from a water table within the profile). Where this horizon is at the surface, there may be a polygonal pattern of slightly elevated ridges caused by surface heaving as the salt crystals accumulate. In the laboratory, the salt concentration is evaluated by measuring electrical conductivity of a saturated paste extract. The level of salt concentration may vary seasonally as salts are partially leached during rainy periods and accumulate through evapotranspiration during dry periods.

Generalized Characteristics

1) Thickness is $\geq$ 15 cm.
2) For $\geq$ 90 consecutive days in most years:
    a. Electrical conductivity in a saturated paste extract (EC_e) is $\geq$ 30 dS/m, *and*
    b. Product of EC_e X horizon thickness (cm) is $\geq$ 900.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon A or B combined with suffix z. Additional suffixes g, k, or y may also be used. Examples include: Az, Bzg, and Bzky.



A salic horizon has formed in the upper part of this profile due to upward movement of salts from the water table (below the view of the photo). The land surface is white due to the accumulating salt crust.

Back to Salic Horizon

Sapric Soil Materials

Organic soil materials that are highly decomposed

Concept and Background Information

Sapric soil materials are organic soil materials that are highly decomposed. They have few fibers (<~ 1/3, by volume) that can be identified, before rubbing, as to their biological origin. After rubbing, <~ 1/6 (by volume) intact fibers remain.

A simple field test involves rubbing the material between the fingers (about ten times) to observe the amount of intact fiber that persists after rubbing. Sapric soil materials generally have relatively high bulk density (>~ 0.2 g/cm^3) and a relatively low water content when saturated (commonly <~ 450%, by weight, compared to oven dry). Sapric soil materials are commonly very dark gray to black.

Note: For comparison, see the less decomposed hemic and fibric soil materials.

Generalized Characteristics

1) Material contains < 1/6 (by volume) fibers after rubbing, *and*
2) Material yields a brownish yellow to black extract of sodium pyrophosphate solution.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon O combined with suffix a, as in Oa.

Organic soil materials, including fibric (top), hemic (middle), and sapric (lower) materials. (Photo courtesy of John Kelley)

Return to Sapric Soil Materials

Slickensides

Subsoil feature consisting of polished and grooved surfaces caused by shrinking and swelling

Concept and Background Information

Slickensides are polished and grooved features on subsoil structural surfaces that are produced as one soil mass slips past another. The soil masses move because of shear failure due to significant shrinking and swelling caused by wetting and drying cycles. Slickensides are only found in soils with high contents of swelling clay minerals (smectite) that are subject to at least periodic wetting and drying. They are one of the diagnostic criteria used to identify Vertisols.

Generalized Characteristics

1) Surfaces are polished (commonly shiny) and grooved.
2) Dimensions are generally > 5 cm and commonly much larger.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B or C combined with suffix ss, sometimes in combination with suffix g, k, n, or t. Examples include: Bss, Bssg, and Css.

Slickensides in a Vertisol.

Soil Temperature Regimes

Concept and Background Information

The soil temperature regimes are defined by mean annual soil temperature (MAST) at a depth of 50 cm from the soil surface, or shallower depth if a root-limiting layer is present. Mean summer soil temperature (MSST) at the same depth is used in the cryic regime definition.

See the generalized map of soil temperature regime regions in the continental United States.

Note: For information regarding the estimation of these criteria, see the discussion of soil temperature regimes in Part 1—How to Use This Version of the Keys.

General Characteristics

The temperature regimes, arranged from coldest to warmest:

1. **Gelic** – Too cold for virtually all crops; very cold MAST (≤ 0 °C)
2. **Cryic** – Too cold for virtually all crops; cold MAST (< 8 °C) and also cold in summer
3. **Frigid** – Too cold for all but cold weather crops, such as wheat, oats, or barley; cold MAST (< 8 °C) but warmer in summer than the cryic regime
4. **Mesic** – Suited to crops such as corn, wheat, and soybeans; moderate MAST (8 - < 15 °C)
5. **Thermic** – Suited to warm weather crops such as cotton; warm MAST (15 - < 22 °C)
6. **Hyperthermic** – Suited to citrus and other freeze-intolerant crops; hot MAST (≥ 22 °C)

Note: MAST = mean annual soil temperature; MSST = mean summer soil temperature.

Sombric Horizon

Subsoil horizon with an illuvial accumulation of humus

Concept and Background Information

The sombric horizon is a dark-colored subsoil horizon with an illuvial accumulation of humus. Compared to the layer above, the sombric horizon has lower color value and/or chroma. The humus is not complexed with aluminum (as in the spodic horizon), is not dispersed with sodium (as in some natric horizons), and is not associated with illuvial silt and clay (as in the agric horizon). There is no albic horizon above a sombric horizon.

Sombric horizons form in cool, moist, high-elevation areas in tropical and subtropical regions. As a result of high leaching in this environment, base saturation (measured by NH_4OA_c) is < 50%. The cation-exchange capacity (CEC) associated with the clay fraction is much lower than that of the spodic horizon; the spodic horizon has a significant amount of amorphous minerals (not present in the sombric horizon) that provide high CEC. Because of its dark color, the sombric horizon may be mistaken for a buried surface layer. However, upon close examination, it is evident that the dark-colored humus is rather concentrated on ped surfaces and pore linings than occurring throughout the matrix.

Generalized Characteristics

1) Horizon is a dark-colored subsoil layer with illuvial humus (not complexed with aluminum) that has:
    a. Lower color value and/or chroma than layer above, and
    b. The appearance of a buried surface layer (but is not).
2) Base saturation (NH_4OA_c) is < 50%.
3) Horizon does not underlie an albic horizon.
4) Horizon occurs in cool, moist, high-elevation areas in tropical and subtropical regions.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B combined with suffix h and generally o, as in Bho.

Profile of a high-elevation, tropical soil. The dark layer in the middle is a sombric horizon.

Return to Sombric Horizon

Spodic Horizon

Subsoil horizon with an illuvial accumulation of organic matter in complex with aluminum and also commonly iron

Concept and Background Information

The spodic horizon is a subsoil horizon with an illuvial accumulation of active amorphous materials that consist of organic matter in complex with aluminum and also commonly iron. These materials are defined as spodic materials. The spodic horizon contains ≥ 85% spodic materials. The spodic materials impart unique properties to the soil, including a high cation-exchange capacity, a large surface area, high water retention, reddish color, low pH, and a high content of organic carbon.

The spodic horizon forms in humid environments, both cold and hot. Native vegetation favoring the production and illuviation of organo-metal complexes is important to the formation of the spodic horizon. In cool climates, this vegetation includes heath as well as both coniferous and mixed broadleaf forest. In warm climates, it includes savannah, palm, and mixed forest. Spodic horizons tend to form on sandy or loamy parent materials with < ~ 20% clay. Some are gravelly. They form in both well drained and poorly drained conditions. In wet conditions, however, it seems important that the water table fluctuate and not remain at the surface.

Generalized Characteristics

1) Thickness is ≥ 2.5 cm.
2) Horizon contains ≥ 85% spodic materials.
3) Horizon formed as a subsoil horizon.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon B combined with suffix s and/or h. Examples include: Bs, Bhs, and Bh.

Reddish spodic horizon below a light gray albic horizon.

Back to Spodic Horizon

Spodic Materials

Illuvial, active amorphous materials composed of organic matter in complex with aluminum and also commonly iron

Concept and Background Information

Spodic materials are active amorphous materials that have been illuviated into a subsurface horizon. They are composed of organic matter that is in complex with aluminum and also commonly iron and are moderately acid or more strongly acid in reaction. They impart unique properties to the soil, including a high cation-exchange capacity, a large surface area, high water retention, reddish color, low pH, and a high content of organic carbon. Spodic materials are used in the definition of the spodic horizon.

In many cases, the presence of spodic materials can be confirmed by low pH, a high content of organic carbon, certain black to dark brown or reddish colors, and the presence of an overlying albic horizon. In cases where either there is no albic horizon or the colors below the albic are too high in chroma, additional evidence (as described in the next paragraph) is required.

In some cases, the active amorphous materials form cracked coatings on sand grains that can be seen with a 40-60X hand lens (especially when dry). In extreme cases, this can lead to the cementation of a substantial part of the layer. Evidence for the illuvial nature of the material can be gained using the optical-density-of-the-oxalate-extract test (ODOE). The ODOE value of illuvial spodic materials is higher than that of the overlying eluvial layer. This reflects the translocation of organic materials into the illuvial layer. The Al + ½ Fe (by ammonium oxalate) test is used to conform illuviation of aluminum and iron.

Generalized Characteristics

1) All spodic materials have:
    a. pH $\leq$ 5.9 (1:1 water), and
    b. $\geq$ 0.6% organic carbon.
2) If a mostly continuous albic horizon is present, color below the albic has:
    a. Hue 5YR or redder, or
    b. Hue 7.5YR, value $\leq$ 5, and chroma $\leq$ 4, or
    c. Hue 10YR (or neutral hue) and value and chroma $\leq$ 2, or
    d. Hue 10YR 3/1, or
    e. Hue 7.5YR, value $\leq$ 5, and chroma 5 or 6.

    For item e only, go to item 4; otherwise stop.
3) If there is no albic horizon above, color is:
    a. Any color listed for item 2

Plus

4) Additional properties are required in cases of items 2e or 3a. In these cases, materials *must:*
   a. Be very firm or firmer and cemented (air-dry fragment does not slake), *or*
   b. Have ≥ 10% cracked coatings on sand grains, *or*
   c. Have Al + ½ Fe (by ammonium oxalate) ≥ 0.50 and ≥ 2 times more than in the layer above, *or*
   d. Have ODOE > 0.25 and ≥ 2 times more than in the layer above.

Common Horizon Nomenclature

There is no horizon nomenclature specifically used to indicate the presence of spodic materials, although they are often associated with a spodic horizon and the nomenclature associated with it. In some areas, plowing has mixed spodic materials into the surface layer, which is simply indicated with master horizon A and suffix p.

Sulfidic Materials

Soil materials containing acid-producing, oxidizable sulfur compounds

Concept and Background Information

Sulfidic materials contain oxidizable sulfur compounds, such as elemental sulfur, pyrite, or iron-monosulfides. They generally accumulate in permanently saturated sediments associated with brackish waters, such as coastal marshes, estuaries, and mouths of rivers. They can also accumulate in fresh water systems if sulfur is present in the water. While commonly associated with coastal environments, sulfidic materials also are known to occur in deep strata in upland positions where the sulfidic materials were deposited in the geologic past under previous environmental conditions. If exposed to the atmosphere, the sulfur compounds will oxidize to form sulfuric acid and the pH will become very low, thus forming a sulfuric horizon. The conversion of sulfidic materials into a sulfuric horizon can occur over a period of a few weeks to a few months.

Generalized Characteristics

1) Initial pH is > 3.5 (1:1 water).
2) Materials have one or both of the following:
    a. After aerobic incubation for 16 weeks, a pH that drops to ≥ 0.5 unit (to final pH of ≤ 4.0), *and/or*
    b. A sulfur dry weight that is:
        i. ≥ 0.75% *and*
        ii. More than 1/3 the calcium carbonate equivalent.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon O, A, B, or C with suffix se, often in combination with a, e, or g. Examples include: Oase, Bseg, and Cseg.

Sulfuric Horizon

Horizon that has become highly acid due to oxidation of sulfide minerals

Concept and Background Information

The sulfuric horizon is a horizon that has become highly acid due to oxidation of sulfide minerals. It can be in the subsoil or at the surface. Sediments deposited in salt- or brackish-water environments, whether in today's coastal areas or in inland ancient seas, may contain iron-sulfide minerals that, upon exposure to air, produce sulfuric acid. The sulfuric horizon commonly forms as a result of human activity, such as drainage, dredging, surface mining, or other earth-moving activities that expose the sulfur-bearing materials to the air. Natural processes, such as landslides on mountain slopes, can also expose sulfur-bearing soil materials to oxidation. After exposure, sulfuric acid forms. In some cases, distinctive minerals such as jarosite (with a characteristic straw-yellow color) also form. The highly acidic materials are toxic to plants and negatively affect structures built upon them.

Generalized Characteristics

1) Thickness is ≥ 15 cm.
2) pH is ≤ 3.5 (or < 4.0 if sulfide or sulfur-bearing minerals are present).
3) Horizon shows evidence that low pH is due to sulfuric acid. It has:
    a. Jarosite concentrations (straw-yellow color, commonly hue of 2.5Y or yellower and chroma of ≥ 6), *or*
    b. ≥ 0.05 water-soluble sulfate, *or*
    c. Sulfidic materials directly below.

Common Horizon Nomenclature

Commonly used horizon nomenclature includes master horizon O, A, or B combined with suffix j, often in combination with a, e, g, or se. Where the horizon formed in human-transported material, the master horizon is preceded by the caret symbol (^). Examples include: Oaj, Bjseg, and ^Apj.

Jarosite concentrations (yellow) within peds from a sulfuric horizon.

Return to Sulfuric Horizon

Udic Moisture Regime (Humid Areas)

Regime characteristic of humid regions with seasonally well distributed precipitation

Concept and Background Information

The udic soil moisture regime is in humid regions with seasonally well distributed precipitation. The soils are not dry for ≥ 90 cumulative days in most years. In general, the combination of stored moisture and moisture from summer equals or exceeds that lost through evapotranspiration.

See the generalized map of soil moisture regime regions in the continental United States.

Generalized Characteristics

1) Soil is dry < 90 cumulative days in most years.
2) Soil is dry < 45 consecutive days in summer and early fall (except in very warm areas and locations where there is little difference between summer and winter soil temperatures).

Note: For information regarding the estimation of these criteria, see the discussion of soil moisture regimes in Part 1—How to Use This Version of the Keys.

Ustic Moisture Regime (Semiarid Areas)

Regime characteristic of semiarid climates where moisture is limited but available for portions of the growing season

Concept and Background Information

The ustic soil moisture regime is intermediate between the aridic (dry) and udic (moist) soil moisture regimes. Although the overall annual moisture amounts are limited, moisture is generally available during portions of the growing season. Unlike soils with a xeric regime, where they receive moisture mostly in winter, soils with an ustic soil moisture regime receive precipitation mostly in spring and summer or spring and fall. The ustic soil moisture regime is not used for soils with permafrost.

See the generalized map of soil moisture regime regions in the continental United States.

Generalized Characteristics

1) In areas that have very warm average annual soil temperature (≥ 22 °C) or that have little difference (< 6 °C) between winter and summer soil temperatures:
    a. The soil is dry for ≥ 90 cumulative days during the year, but
    b. The soil is moist during the year for ≥ 90 consecutive days or > 180 cumulative days.
2) In other areas with cold to warm soil temperatures (< 22 °C):
    a. The soil is dry for ≥ 90 cumulative days, but
    b. The soil is moist is for ≥ 50% of the growing season (when soil temperature > 5 °C).
3) In other areas where the soil is moist for ≥ 45 consecutive days in winter and early spring, the soil is dry for < 45 consecutive days in summer and early fall.

Xeric Moisture Regime

Regime characteristic of a Mediterranean-type climate with cool, moist winters and warm, dry summers

Concept and Background Information

The xeric soil moisture regime is characterized by a Mediterranean-type climate, in which winters are cool and moist and summers are warm and dry. Most precipitation falls during winter, when evapotranspiration is low, which generally allows ample storage of moisture for the following growing season. The xeric soil moisture regime is not used in areas that have very warm average annual soil temperatures (≥ 22 °C) or that have little difference (< 6 °C) between winter and summer soil temperatures. The soils are dry for ≥ 45 consecutive days in summer and early fall and moist for ≥ 45 consecutive days in winter and early spring.

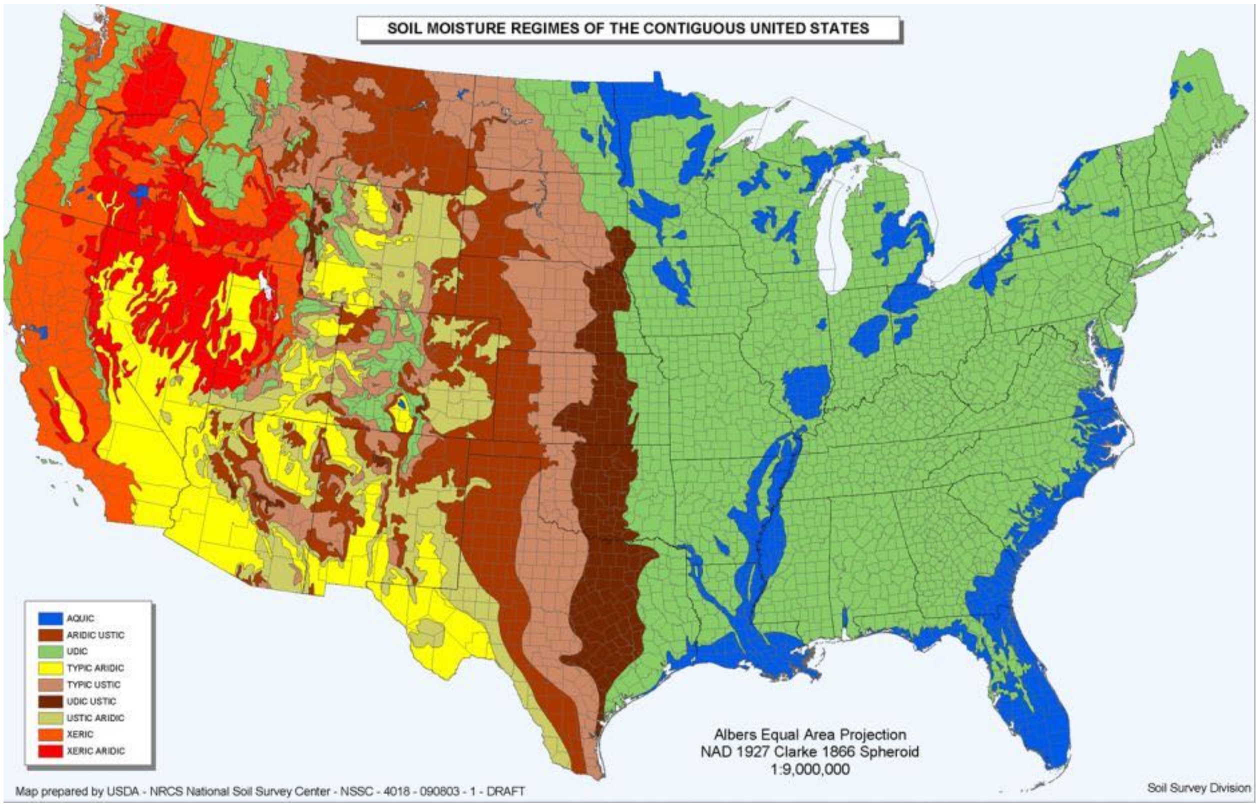
See the generalized map of soil moisture regime regions in the continental United States.

Generalized Characteristics

1) The soil is moist for ≥ 45 consecutive days in winter and early spring and dry for ≥ 45 consecutive days in summer and early fall.
2) The soil is moist is for ≥ 50% of the growing season (when soil temp is > 5 °C).

Moisture Regime Map

This map shows the general pattern of soil moisture regimes across the United States. The classes shown include moisture intergrades, such as typic ustic and xeric aridic, that are used at the subgroup level of Soil Taxonomy. For classification at the great group level, only consider the second term (e.g., consider xeric aridic as just aridic).This map can be used as a general guide for assigning a moisture regime class, but it is not definitive for any specific location.

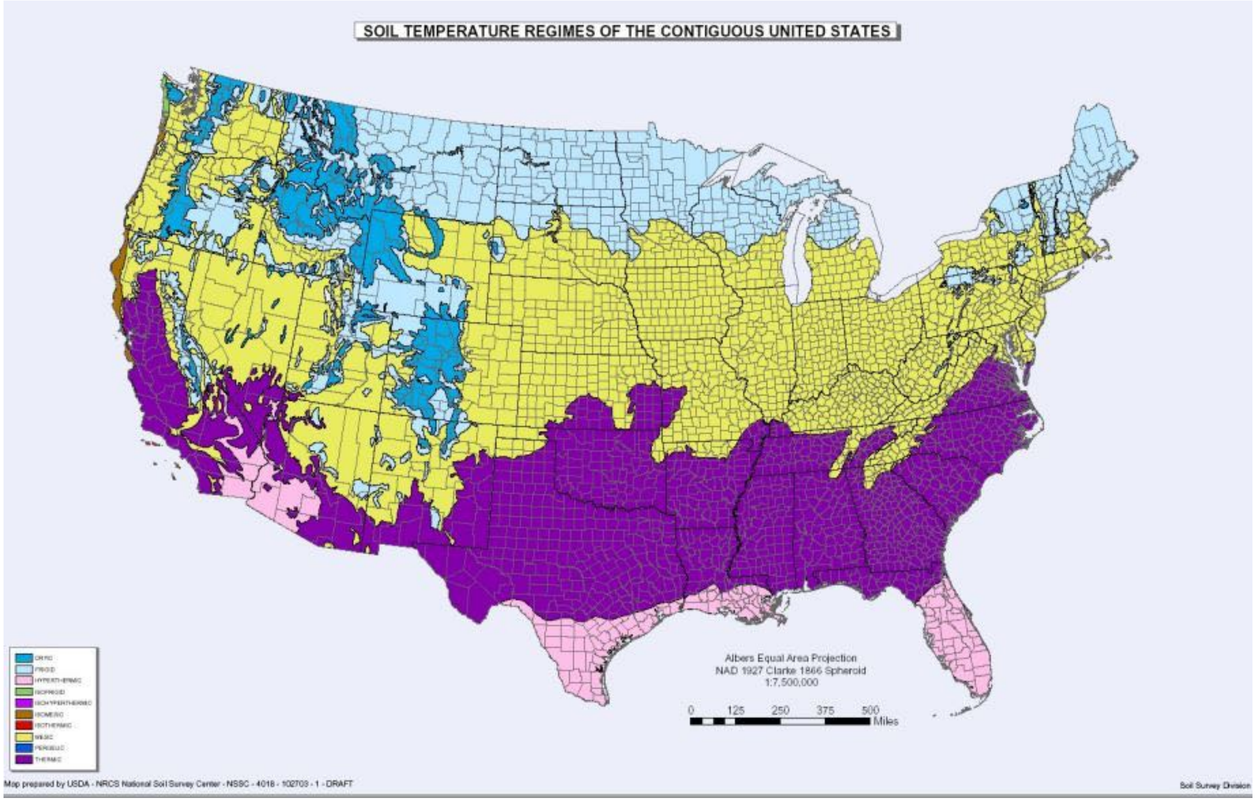

SOIL MOISTURE REGIMES OF THE CONTIGUOUS UNITED STATES

Map prepared by USDA - NRCS National Soil Survey Center - NSSC - 4018 - 090803 - 1 - DRAFT

Return to:
Aquic Soil Moisture Regime
Aridic Soil Moisture Regime
Perudic Soil Moisture Regime
Udic Soil Moisture Regime
Ustic Soil Moisture Regime
Xeric Soil Moisture Regime

Temperature Regime Map

This map shows the general pattern of soil temperature regimes across the continental United States. Gelic temperature regimes have not been documented in the continental United States but are found in Alaska. This map can be used as a general guide for assigning a moisture regime class, but it is not definitive for any specific location.



Return to Soil Temperature Regimes

Part 4—Keys to the Orders, Suborders, and Great Groups

Key to Soil Orders

Introduction

The keys are designed to be used sequentially, beginning with the key to the orders, then that of the suborders, and finally that of the great groups. Start with the first item listed in the key to orders and determine whether or not the soil meets the criteria. If the initial criteria listed are not met, continue through the key until the criteria are met. Once the criteria for the order are determined to be met, move on to the suborder and then the great group. The design of the keys is such that a soil is placed in the first class for which the criteria are met.

The criteria presented in the keys refer to the presence of specific diagnostic horizons and characteristics. In addition, some require a determination of the proper moisture or temperature regime. See Part 3—Diagnostic Horizons and Characteristics for detailed information. Unless otherwise specified, depths are measured from the soil surface.

At the highest level of the classification system, twelve soil orders are recognized. The orders, along with a brief description capturing the general concept of each, are presented (alphabetically) in the list below. After these descriptions is a key for determining the order in which a soil belongs. Keys for determining the proper suborder and great group follow.

Brief Description of the Soil Orders

1. **Alfisols** are naturally fertile soils with high base saturation and a clay-enriched subsoil horizon.

2. **Andisols** are relatively young soils, mostly of volcanic origin, that are characterized by unique minerals with poorly organized crystalline structure.

3. **Aridisols** are the dry soils of deserts.

4. **Entisols** are young soils with little or no profile development.

5. **Gelisols** are very cold soils with permafrost in the subsoil.

6. **Histosols** are soils that formed in decaying organic material.

7. **Inceptisols** are youthful soils with a weak, but noticeable, degree of profile development.

8. **Mollisols** are very dark-colored, naturally very fertile soils of grasslands.

9. **Oxisols** are highly weathered tropical soils with low natural fertility.

10. **Spodosols** are acid soils with low fertility and accumulations of organic matter and iron and aluminum oxides in the subsoil.

11. **Ultisols** are soils with low base status and a clay-enriched subsoil.

12. **Vertisols** are very clayey soils that shrink and crack when dry and expand when wet.

Key to Soil Orders

A. **Soils (mineral or organic) with permafrost within a depth of 200 cm --- Gelisols**
If the permafrost is below a depth of 100 cm, then gelic materials must also be present (i.e., evidence of cryoturbation) above 100 cm.

B. **Soils with organic material 40 cm or more thick ----------------- Histosols**
In most cases, the organic soil materials must be ≥ 40 cm thick. There are exceptions, however, that allow thinner amounts, i.e., where the organic layers directly overlie very coarse textured materials and where the soils are relatively shallow to some root-limiting layers. The organic layers must be ≥ 60 cm thick if they are from sphagnum moss or other organic material with a very low bulk density. Also, Histosols are not allowed to contain significant amounts of andic soil materials in the upper part.

C. **Soils with a spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) horizon that is 10 cm or more thick within a depth of 50 cm (or within 200 cm if the soils have sandy texture above the spodic horizon)------------------ Spodosols**
Spodosols cannot have a plaggen, argillic, or kandic horizon above the spodic horizon. If andic soil materials are present in the upper part of the soil, then there must be an albic horizon above the spodic. See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding Spodosols that are very cold, loamy, cemented, or plowed or that have root-limiting layers.

D. **Soils with andic soil properties (rich in volcanic glass or poorly crystalline minerals) in 36 cm or more of the upper 60 cm -- Andisols**
Begin measuring from the top of the mineral soil or the top of an O horizon that has andic properties, whichever is shallowest. For soils with certain

root-limiting layers above a depth of 60 cm, andic soil properties must constitute $\geq$ 60% of the zone above the root-limiting layer.

E. Soils with an oxic (extremely weathered) horizon within a depth of 150 cm ---Oxisols
A kandic horizon may be present within a depth of 100 cm providing it has < 10% weatherable minerals in the fine and very fine sand fractions and there is $\geq$ 40% clay in the upper 18 cm of the soil (after mixing).

F. Soils with all of the following:

a) 30 percent or more clay to a depth of at least 50 cm, AND

b) Evidence of shrinking and swelling (slickensides) in a layer 25 cm or more thick above a depth of 100 cm, AND

c) Cracks that open and close periodically ------------------------- Vertisols
The top 18 cm of surface soil (or a plow layer) may have sublayers with less than 30% clay, as long as the overall average is $\geq$ 30%. Also, the 50-cm depth criterion is waved if the layer with a high clay content is underlain directly by certain root-limiting layers.

G. Soils that have either:

a) An aridic soil moisture regime (too dry for mesophytic plants) and a diagnostic subsoil horizon, OR

b) A salic (high content of salts) horizon underlain by a seasonal high water table within a depth of 100 cm -------------------------------- Aridisols
Aridisols must have either an ochric (typically thin and/or light-colored) or anthropic (human-modified) epipedon. Other diagnostic horizons, except argillic (clay accumulation) or natric (high levels of illuvial clay and sodium) horizons, must begin above a depth of 100 cm. Aridisols cannot have a sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon within a depth of 150 cm. The moisture control section of Aridisols with a seasonal high water table must be dry at some time during the year.

H. Soils with both:

a) An argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon AND

b) Base saturation (by sum of cations) of less than 35 percent at the check depth (generally 125 cm below the top of the argillic or kandic horizon) -- Ultisols

The check depth varies for soils with sandy surface layers, for soils with a kandic or argillic horizon that begins deeper than 55 cm, and for soils with a fragipan or certain other root-limiting layers.

I. Soils with both:

a) A mollic (rich in humus and bases) epipedon AND

b) Base saturation of 50 percent or more in all layers, generally to a depth of 180 cm --- Mollisols
Exceptions to the criterion of a depth of 180 cm are 125 cm below the top of an argillic, kandic, or natric horizon or to a densic, lithic, or paralithic contact, providing any of these are shallower than 180 cm. Also, special provisions are made for some soils with an intervening albic horizon within the mollic epipedon.

J. Soils with an argillic (clay accumulation), kandic (very low cation-exchange capacity), or natric (high levels of illuvial clay and sodium) subsoil horizon or a fragipan (firm and brittle but not cemented layer)--- Alfisols
To qualify as an Alfisol, the fragipan must have clay films more than 1 mm thick.

K. Soils that have either:

a) Within a depth of 100 cm, a cambic (minimal soil development), calcic (calcium carbonate accumulation), petrocalcic (cemented by calcium carbonate), gypsic (gypsum accumulation), petrogypsic (cemented by gypsum), or placic (cemented by iron and organic matter) horizon or a duripan (layer cemented by silica), OR

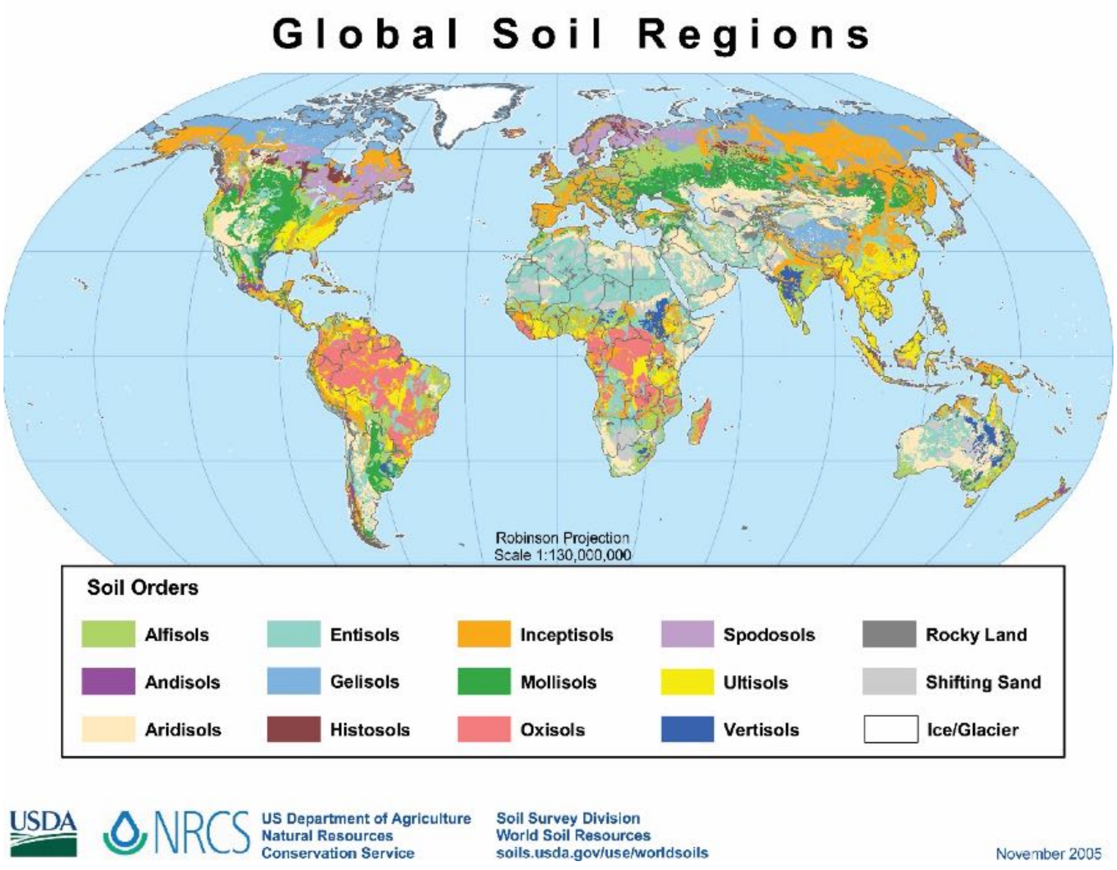
b) Within a depth of 150 cm, a sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon, OR

c) Within a depth of 200 cm, a fragipan (firm and brittle but not cemented layer) or an oxic (extremely weathered), sombric (dark layer in which organic matter has accumulated), or spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) horizon, OR

d) Within the upper 50 cm, a salic (high content of salts) horizon or a histic (wet, organic surface layer), folistic (freely drained organic surface layer), mollic (rich in humus and bases), umbric (humus-rich with low base saturation), or plaggen (human-modified) epipedon, OR

e) Within the upper 50 cm, an exchangeable sodium percentage $\geq$ 15 (sodium adsorption ratio $\geq$ 13), and a seasonal high water table within a depth of 100 cm -- Inceptisols
The base of a cambic horizon must be below a depth of 25 cm, unless the soil has a cryic or gelic temperature regime. For items d and e above, sulfidic materials must not occur within a depth of 50 cm and the soil must be non-fluid or have < 8% clay at some depth between 20 and 50 cm.

L. Soils generally lacking in pedological development ------------- Entisols



Alfisols Order

Alfisols are naturally fertile soils with high base saturation and a clay-enriched subsoil horizon.

General Characteristics

Typically, Alfisols have a surface horizon consisting of an ochric (typically thin and/or light-colored) epipedon and a subsurface consisting of a clay-enriched argillic horizon. Between the surface horizon and subsoil, there is commonly a light-colored zone of leaching. In addition, these soils have moderate to high base saturation. Alfisols may have other subsoil horizon forms, including a fragipan (firm and brittle but not cemented layer), a duripan (layer cemented by silica), a kandic (very low cation-exchange capacity) horizon, a natric (high levels of illuvial clay and sodium) horizon, a petrocalcic (cemented by calcium carbonate) horizon, plinthite (firm, iron oxide-rich concentration), or other features, and these are used in defining the great groups within the order. A few wet Alfisols have an umbric (humus-rich with low base saturation) epipedon.

Environment and Processes

Alfisols formed from a wide range of parent materials and occur under broad environmental conditions, ranging from tropical to boreal. Most Alfisols have a humid (udic) or subhumid to semiarid (ustic) moisture regime. Those with a Mediterranean-type climate, where precipitation occurs mostly in winter and summers are dry, have a xeric moisture regime. Some Alfisols are wet and have an aquic moisture regime.

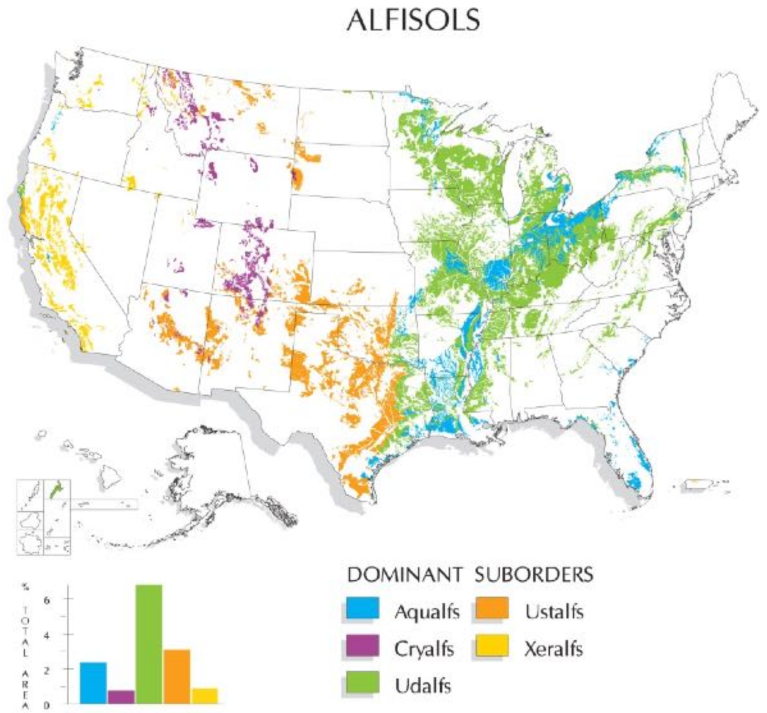
Alfisols have developed primarily (though not exclusively) under forest vegetation. The movement of clay and other weathering products from the upper layers of the soil and their subsequent accumulation in the subsoil are important processes in Alfisols. The soil-forming processes are in relative balance. As a result, nutrient bases (such as calcium, magnesium, and potassium) are supplied to the soil through weathering and the leaching process is not sufficiently intense to remove them from the soil before plants can use and recycle them.

Location

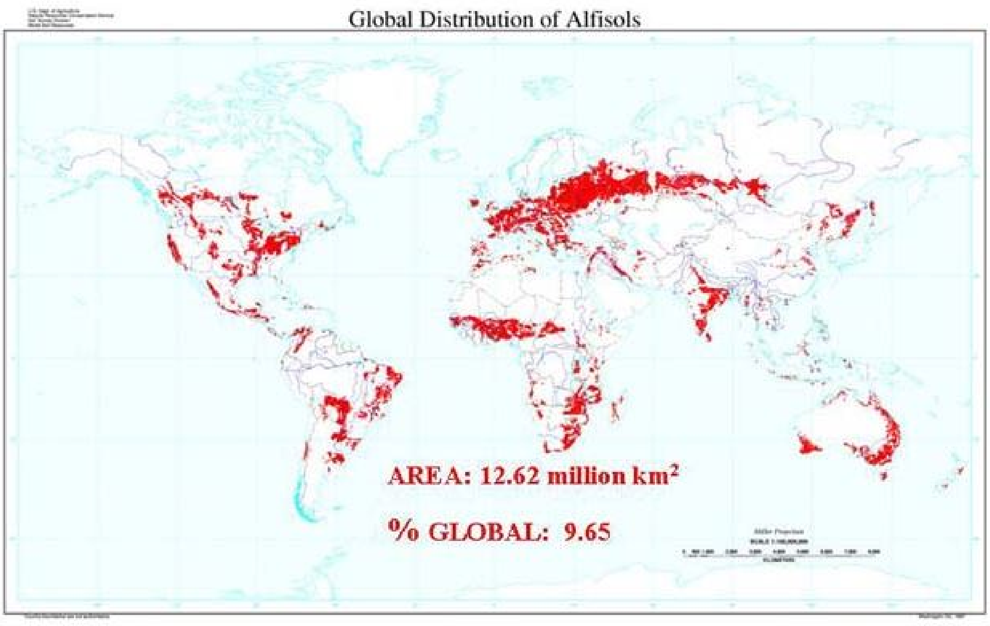
Alfisols are extensive worldwide, occurring on every continent (excluding Antarctica). Globally, they occupy about 10% of the ice-free land area. The Alfisols of the warmer climates tend to form a zone between the Aridisols of arid regions and the Inceptisols, Ultisols, and Oxisols of areas with warm, humid climates. Where the climate is cooler, the Alfisols in the United States tend to form a belt between the Mollisols of the grasslands and the Spodosols and Inceptisols of very humid climates.

Profile of an Alfisol (specifically a Haplustalf) in Stephenville, Texas. (Photo courtesy of Dr. David Weindorf)

(Back to Key to Soil Orders)



Alfisols by suborder in the United States.



Global distribution of Alfisols.

Alfisols Suborders

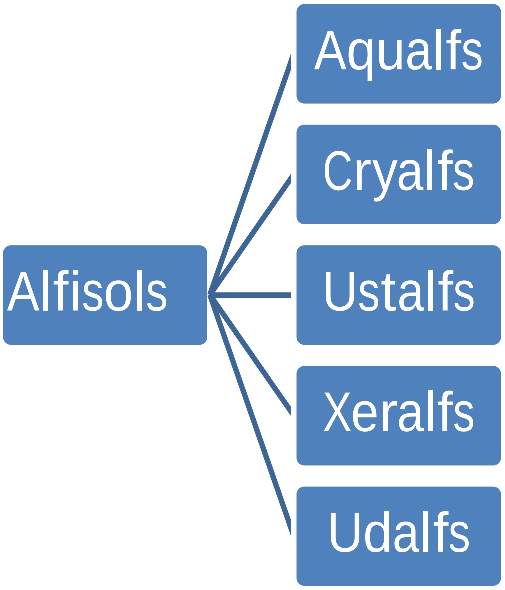
Classification of Alfisols

In the definitions of the suborders, emphasis is placed entirely on soil climate in the form of soil wetness (Aqualfs), cold soil temperature (Cryalfs), and soil moisture regime (Ustalfs, Xeralfs, and Udalfs).

The great group level reflects a combination of important properties, including the presence of diagnostic horizons other than an argillic horizon, cold soil temperature, an abrupt texture change to a slowly permeable layer, dark red colors, iron-cemented nodules in the subsoil, plinthite (firm, iron oxide-rich concentration) in the subsoil, patterns of soil saturation, intense bioturbation from earthworms or other organisms, and morphology reflecting strong soil development on stable landforms.

The five suborders are:

1. Aqualfs—wet Alfisols (aquic conditions in upper part)
2. Cryalfs—cold Alfisols (cryic or isofrigid temperature regime)
3. Ustalfs—moderately dry Alfisols (limited moisture)
4. Xeralfs—moderately dry Alfisols (limited moisture that is supplied in winter and a Mediterranean-type climate)
5. Udalfs—Alfisols of humid regions with well-distributed rainfall



Key to Suborders of Alfisols

Alfisols that:

1) **Have a seasonal high water table within a depth of 50 cm ----- Aqualfs**
Redoximorphic features are evidence of a seasonal high water table. Artificially drained sites are included in Aqualfs. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding color, depths, and location for redoximorphic features.

2) **Have cold average soil temperature ------------------------------------- Cryalfs**
These soils have a cryic or isofrigid soil temperature regime.

3) **Have somewhat limited soil moisture available for plant growth -- Ustalfs**
These soils have an ustic soil moisture regime. Moisture is limited, but available, during portions of the growing season.

4) **Have a Mediterranean-type climate -------------------------------------- Xeralfs**
These soils have a xeric soil moisture regime (cool and moist in winter and warm and dry in summer).

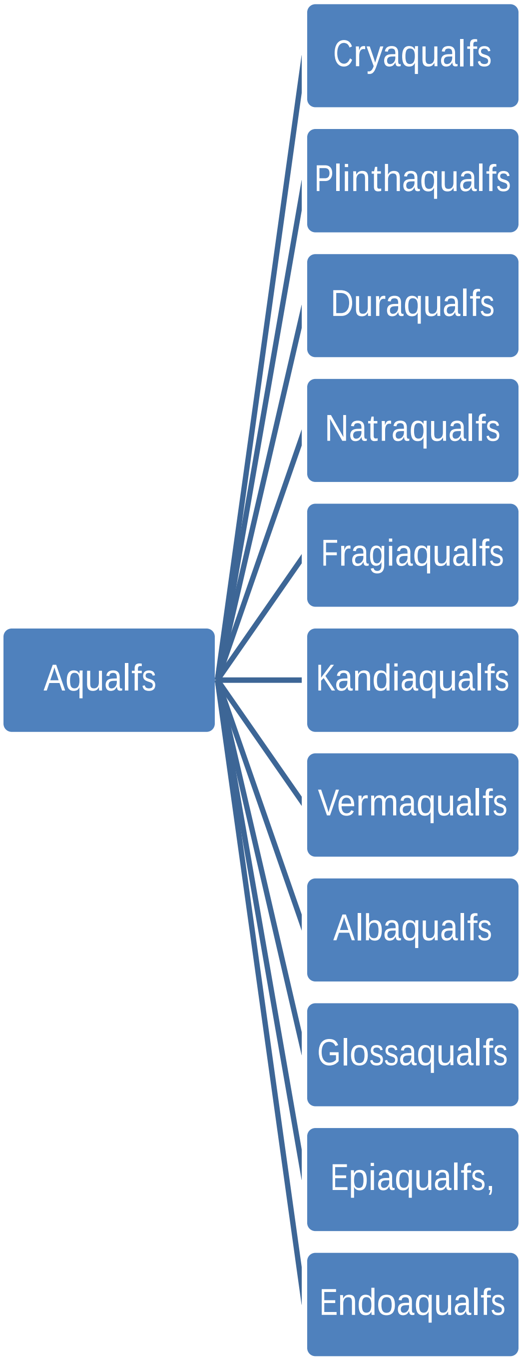
5) **Other Alfisols with seasonally well-distributed precipitation ---- Udalfs**
These soils have a udic soil moisture regime.

Aqualfs Great Groups

Aqualfs are the wet Alfisols. They are saturated close to the surface by ground water for a long enough period during the year to become devoid of oxygen (aquic conditions). Some are artificially drained. Their appearance is commonly characterized by a gray and red mottled color pattern (redoximorphic depletions and concentrations). In some of these soils, ground water is near the surface during a considerable part of the year but drops in another part of the year. In others, the ground water may be deep most of the year but horizons that have low hydraulic conductivity restrict the downward movement of water and extend the period of saturation.

Aqualfs occur in low landscape positions, such as flood plains, depressions, and broad flats. A few may be on side slopes where water seeps laterally over restrictive layers to the surface.

Many Aqualfs are drained and used for cultivated crops. Rice is a common crop on the Aqualfs that have a thermic or warmer temperature regime. Before they were cultivated, some Aqualfs were under forest vegetation or under grass. Nearly all Aqualfs are believed to have supported forest vegetation at some time in the past.


Aqualfs
Cryaqualfs
Plinthaqualfs
Duraqualfs
Natraqualfs
Fragiaqualfs
Kandiaqualfs
Vermaqualfs
Albaqualfs
Glossaqualfs
Epiaqualfs,
Endoaqualfs

Profile of an Aqualf (specifically an Endoaqualf) in Wyoming. The dark surface layer is an umbric epipedon. The subsoil has the characteristic gray and red mottled color pattern that indicates the presence of aquic conditions. Scale is in cm.

Return to Aqualfs

Key to Great Groups of Aqualfs (Back to key to suborders)

Aqualfs that have:

1. **Cold average soil temperature (cryic temperature regime) -- Cryaqualfs**
2. **Plinthite making up ≥ 50% of a layer between depths of 30 and 150 cm -- Plinthaqualfs**
   Begin measuring depth below any O horizon. Plinthite is a firm, iron oxide-rich mass that irreversibly hardens after exposure to repeated wet-dry cycles.
3. **A duripan (layer cemented by silica) ----------------------------- Duraqualfs**
4. **A natric (high levels of illuvial clay and sodium) horizon --- Natraqualfs**
5. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm -- Fragiaqualfs**
   Begin measuring depth below any O horizon.
6. **A kandic (very low cation-exchange capacity) horizon--- Kandiaqualfs**
7. **Significant evidence of bioturbation --------------------------- Vermaqualfs**
   A total of > 25 cm (within a depth of 100 cm) with > 50% evidence of bioturbation is required. Begin measuring depth below any O horizon.
8. **An abrupt increase in clay content to the argillic horizon -- Albaqualfs**
   See "abrupt texture change" definition for specific criteria. Also, the K_{sat} class must be moderately low or lower in the argillic horizon (most likely to be met if the texture is sandy clay, silty clay, or clay).
9. **A glossic (degraded argillic) horizon -------------------------- Glossaqualfs**
10. **Episaturation (perched water table) ------------------------------ Epiaqualfs**
11. **Endosaturation (saturated throughout the profile) --------- Endoaqualfs**

Descriptions of Great Groups of Aqualfs

Cryaqualfs—These are the cold Aqualfs. These soils are not known to occur in the United States. The group has been proposed for other countries, but definitions of subgroups have not been suggested. (Back to Aqualfs key)

Plinthaqualfs—These soils have plinthite (firm, iron oxide-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles) constituting one-half or more of the volume in some subhorizon between depths of 30 and 150 cm. They are mainly in depressions in areas of wet-dry tropical and subtropical climates. They are not known to occur in the United States, but they are reported to be extensive in Africa south of the Sahara. They are perhaps the Alfisols the least used for agriculture, at least in part because they tend to be too wet in the rainy season and too dry in the dry season for most crops. On most of these soils, the vegetation is or was savanna or a deciduous broadleaf forest. (Back to Aqualfs key)

Duraqualfs—These soils have a silica-cemented duripan. Duraqualfs are not known to occur in the United States. The group has been proposed for other countries, but definitions of subgroups have not been suggested. (Back to Aqualfs key)

Natraqualfs—These soils have a clay-enriched subsoil with high levels of sodium saturation (natric horizon). Typically, ground water perches above the natric horizon at some period and saturates the soil at another period. Natraqualfs are allowed, but not required, to have a glossic (degraded argillic) horizon. In the United States, most of these soils have a mesic, thermic, or hyperthermic temperature regime but a few are frigid. If undisturbed, Natraqualfs commonly have a thin A horizon overlying a thin albic (light-colored and leached) horizon that, in turn, overlies the natric subsoil horizon. If the soils are plowed, the two upper horizons and part of the natric horizon or only part of the two upper horizons may be mixed. In the United States, the vegetation on Natraqualfs before cultivation was most commonly grass or mixed grass and drought-tolerant trees. In humid regions where annual precipitation is 100 cm or more, the presence of sodium generally is attributed to very slow permeability in the natric horizon. The permeability is so slow that there is thought to be less leaching of sodium than there is release of sodium by the weathering of feldspars. Many Natraqualfs in the United States formed in loess or alluvium of Wisconsinan age. Some Natraqualfs are in basins or on lowlands and are subject to flooding, and the sodium in them may be supplied by salty ground water or sea water. Characteristically, areas of Natraqualfs are small. (Back to Aqualfs key)

Profile of a poorly drained Natraqualf in Thailand. The sandy surface layer is underlain by a pinkish gray subsoil beginning at a depth of about 15 cm. The subsoil has a weak grade of prismatic structure and a high content of sodium. This soil is used for rice production. Note the water table at a depth of about 145 cm. Scale is in cm.

Return to Natraqualfs

Fragiaqualfs—These soils have a dense, brittle layer (fragipan) within 100 cm of the mineral soil surface. Most have ground water that is perched above the fragipan at some period and saturates the soil at another period. In the United States, the soils generally have frigid to thermic temperature regimes. In most years, the albic horizon generally does not become dry but the ground water drops below the base of the fragipan during summer and the soil moisture content is below field capacity at some period. Most Fragiaqualfs in the United States formed in Wisconsinan deposits of late-Pleistocene age and had broadleaf deciduous forest vegetation before they were cultivated. Most of the soils are nearly level. Fragiaqualfs as a group have lower base saturation than other Aqualfs. (Back to Aqualfs key)

Kandiaqualfs—These soils have a clay-enriched subsoil with a very low nutrient-supplying capacity (kandic horizon). They are allowed, but not required, to have a glossic (degraded argillic) subsoil horizon. Characteristically, they are the Aqualfs with the warmest and most humid climates and the most water passing through the profile. They have a relatively low base saturation for soils of this order. The vegetation is mostly tropical or subtropical hardwood forest. Slopes are nearly level or concave. Kandiaqualfs are mostly in tropical and subtropical areas. They are rare in the United States. (Back to Aqualfs key)

Vermaqualfs—These soils have significant bioturbation in the form of filled animal burrows, wormholes, or casts. Krotovinas (filled animal burrows) restrict water movement because they are dense, massive, compact, and stratified. Soil horizons are obliterated where krotovinas occur. Significant amounts of krotovinas in a soil affect soil morphology, soil hydrology, and soil behavior. These soils are known to occur along the coastal plain of Texas where bioturbation is caused by crayfish. (Back to Aqualfs key)

Albaqualfs—These soils have ground water seasonally perched above a slowly permeable clay-enriched argillic horizon. Commonly, a light-colored, leached, albic horizon rests abruptly on the argillic subsoil horizon with virtually no transitional horizon between the two. There is a significant difference in clay content immediately above and below the top of the argillic horizon. In the United States, most Albaqualfs have a mesic, thermic, or hyperthermic temperature regime and, unless the soils are irrigated, the albic horizon is dry for short periods in summer in most years. The dryness seems essential to the genesis of these soils. Thus, Aqualfs in which the albic horizon is rarely dry are in great groups other than Albaqualfs. (Back to Aqualfs key)

Glossaqualfs—These soils have a glossic (degraded argillic) horizon. The glossic horizon is interpreted as evidence that the argillic horizon has been partly destroyed by the dissolution and removal of clay. Tubular intrusions of light-colored albic materials into the argillic subsoil horizon may be formed by the filling of burrows made by crayfish or traces of taproots. Characteristically, these soils are the Alfisols that have the most humid climates and the most water passing through the profile and that have a relatively low base saturation for soils of this order. Before the soils were cultivated, the vegetation was mostly deciduous hardwood forest. The parent materials are largely basic or calcareous sediments of late-Pleistocene age. Slopes are nearly level or concave. Glossaqualfs are mostly in the most northern and southern parts of areas where Aqualfs occur. They generally are in the Great Lakes area and on the Gulf coast. A few are in the Pacific Northwest. Except where the temperature regime is frigid, most of these soils have been drained and are used for cultivated crops. (Back to Aqualfs key)

Epiaqualfs—These soils have a perched water table. Ground water is commonly perched on horizons below the top of the argillic horizon, but it does not saturate the lower part of the profile. The water table fluctuates from a level near the soil surface to below the argillic subsoil horizon and sometimes is not evident. Before cultivation, most Epiaqualfs supported either deciduous broadleaf or coniferous forest. Epiaqualfs are generally nearly level, and their parent materials are typically late-Pleistocene sediments.
(Back to Aqualfs key)

Endoaqualfs—These soils are saturated throughout the profile for some time during the year. The ground water fluctuates from a level near the soil surface to below the argillic subsoil horizon and is sometimes below a depth of 200 cm. Before cultivation, most Endoaqualfs supported either deciduous broadleaf or coniferous forest. They are generally nearly level, and their parent materials are typically late-Pleistocene sediments. (Back to Aqualfs key)

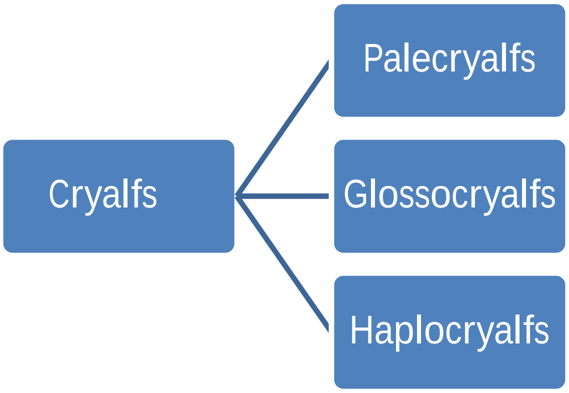
Cryalfs Great Groups

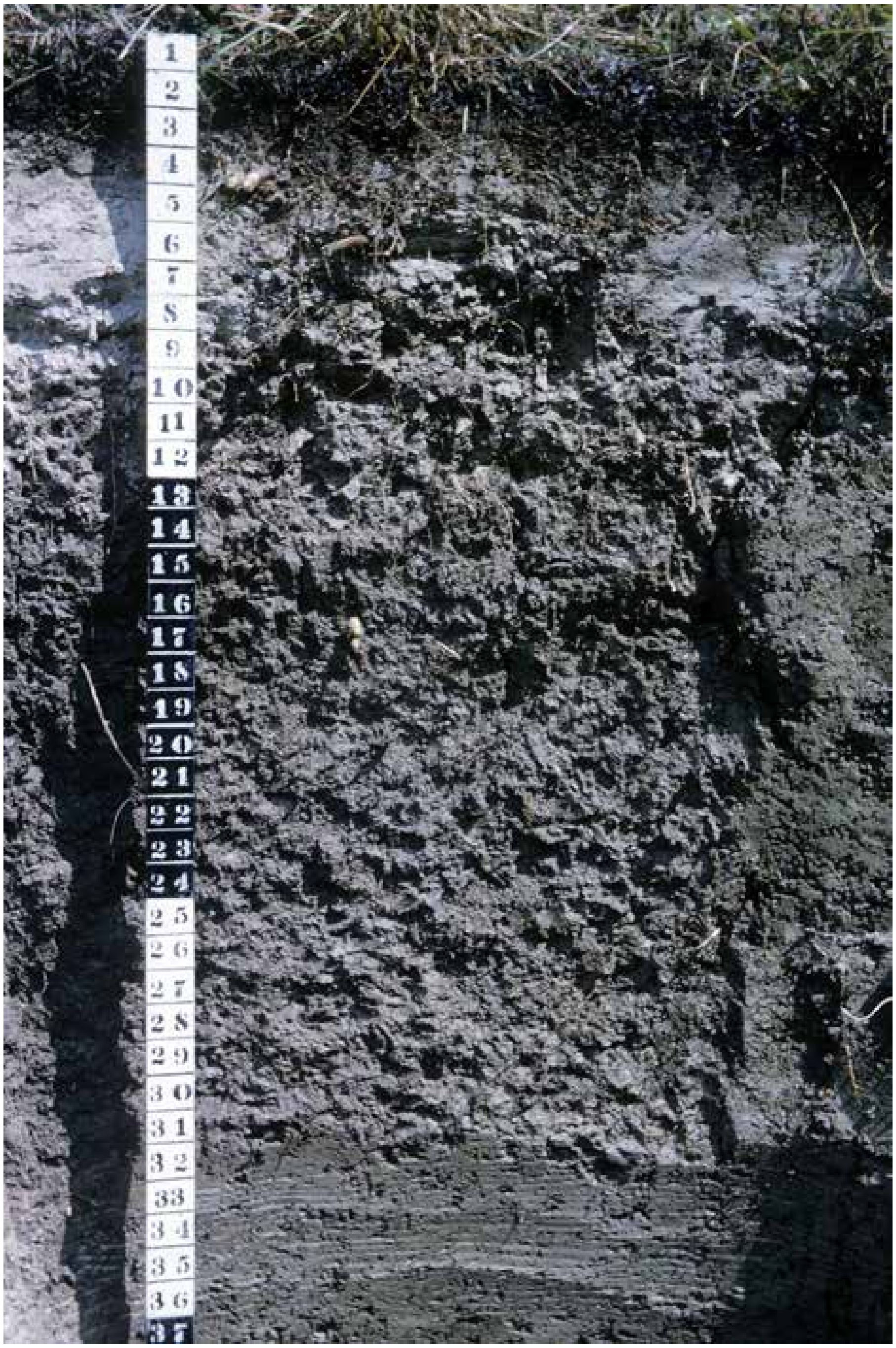
Cryalfs are the more or less freely drained Alfisols of cold regions. Nearly all of these soils have a cryic temperature regime and a udic moisture regime.

Cryalfs are not extensive. They formed in North America, Eastern Europe, and Asia above 49 degrees north latitude and in some high mountains south of that latitude. In the mountains, they tend to form at the lower elevations, adjacent to higher-lying cold Spodosols or Inceptisols. Most Cryalfs are or have been under coniferous forest. In North America, they are mainly in forests because of their short, cool growing season.

Characteristically, Cryalfs have an organic surface layer (O horizon), a light-colored, leached albic horizon, and a clay-enriched argillic subsoil horizon. In some areas, they have a thin, mineral A horizon at the surface. In regions of the least rainfall, they are neutral or slightly acid in all horizons and a calcium carbonate-enriched horizon may underlie the argillic horizon. In many of the more humid areas where they occur, the lower part of the albic horizon and the upper part of the argillic horizon are strongly or very strongly acid.

Cryalfs in the United States generally developed in Pleistocene deposits, mostly of Wisconsinan age.





Profile of a Cryalf (specifically a Haplocryalf) in Canada. This soil has an argillic horizon between depths of about 7 and 26 inches. It formed in finely stratified clayey sediments that were originally deposited under a glacial lake. The fine stratification of the lake sediments can be seen in the smoothed part of the profile below a depth of about 31 inches. Scale is in inches.

Return to Cryalfs

Key to Great Groups of Cryalfs (Back to key to suborders)

Cryalfs that have:

1. **An argillic (clay accumulation), kandic (very low cation-exchange capacity), or natric (high levels of illuvial clay and sodium) horizon beginning at a depth ≥ 60 cm and a glossic (degraded argillic) horizon above -- Palecryalfs**
   Begin measuring below any mantle with vitric volcanic materials, if present. Some layer above the argillic, kandic, or natric horizon must have texture finer than loamy fine sand. A glossic horizon is a kind of degraded argillic horizon. The glossic criterion is waved if there is interfingering of albic materials into the subsoil.

2. **A glossic (degraded argillic) horizon and an argillic horizon within a depth of 60 cm -- Glossocryalfs**

3. **Other simple Cryalfs, with no degradation of the argillic horizon --- Haplocryalfs**

Descriptions of Great Groups of Cryalfs

Palecryalfs—These soils have an albic (light-colored and leached) horizon over a glossic (degraded argillic) subsoil horizon. Some have interfingering of light-colored albic materials into the subsoil. The soils are thought to be restricted to relatively stable surfaces in the mountains, many of which are older than the Wisconsinan Glaciation. The stability may be the result of stoniness. The vegetation on these soils is mostly coniferous forest. The temperature regimes are mostly cryic. The moisture regimes are mostly udic. (Back to Cryalfs key)

Glossocryalfs—These soils have a glossic (degraded argillic) subsoil horizon and typically have an argillic horizon that has an upper boundary within 60 cm of the mineral soil surface (unless there is either a sandy or sandy-skeletal particle-size class throughout the layers above) or there is a surface mantle or layer in the upper 75 cm consisting of slightly or moderately weathered pyroclastic materials. The glossic subsoil horizon commonly has tongue-like projections of light-colored albic materials extending into the argillic horizon. These projections are thought to indicate that the argillic horizon is being moved deeper into the soil. In areas where the soils are transitional between Spodosols and Alfisols, some Glossocryalfs have a cambic (minimal soil development) horizon that appears to be an incipient spodic horizon. The cambic subsoil horizon is commonly separated from the argillic horizon by an albic horizon. The vegetation is mostly coniferous trees. A few Glossocryalfs have been cleared and are used mostly as pasture. (Back to Cryalfs key)

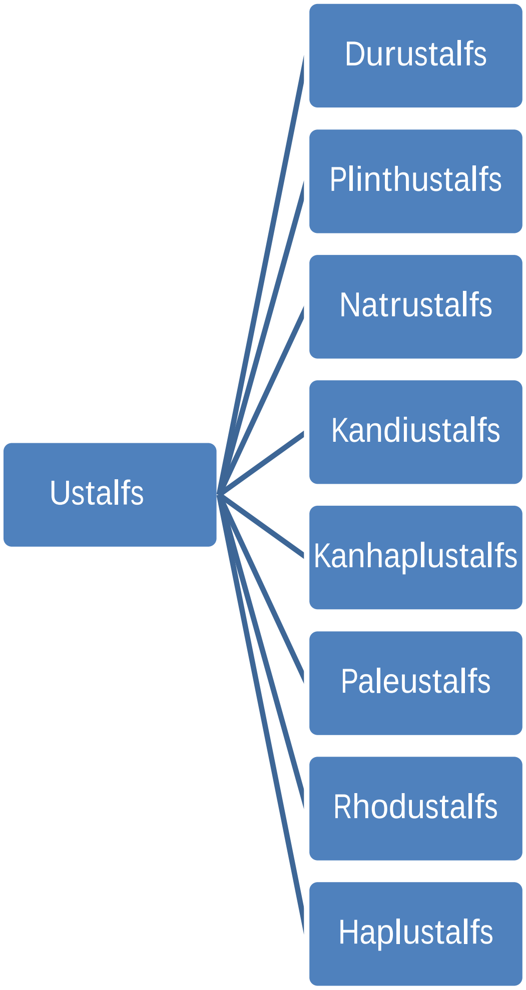
Haplocryalfs—These are the simple Cryalfs with an argillic (clay accumulation) subsoil horizon that has an upper boundary within 60 cm of the mineral soil surface. The common sequence of horizons is an organic surface horizon (O), an albic (light-colored and leached) horizon, and an argillic subsoil horizon. In the United States, Haplocryalfs are in the mountains of western States and have a cold (cryic) temperature regime. Most support coniferous forest vegetation. Virtually none of them are cultivated because their slopes are steep and the growing season is short and cool. In other countries, Haplocryalfs occur on mountains and also on plains nearly as far north as the line of continuous permafrost. Some of the associated soils on these landscapes are Gelisols (soils with permafrost) on north-facing slopes and Histosols (organic soils). (Back to Cryalfs key)

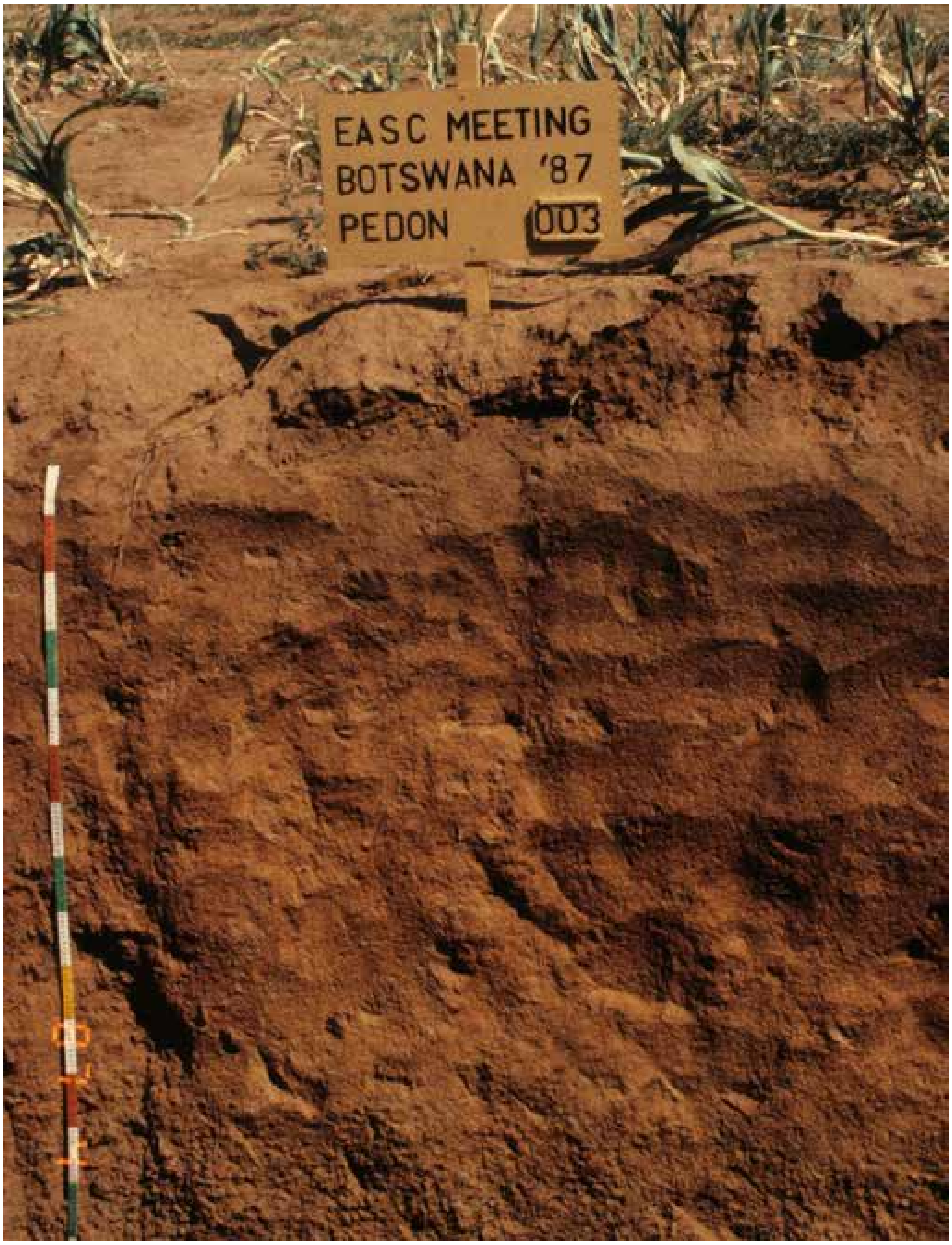
Ustalfs Great Groups

Ustalfs are the Alfisols of cold to warm, subhumid to semiarid regions. They have an ustic moisture regime (moisture is limited, but available, during portions of the growing season). Moisture moves through most of these soils to deeper layers only in some years. If there are carbonates in the parent materials or in the dust that settles on the surface, the soils tend to have a zone of calcium carbonate accumulation below or in the subsoil. The dry season or seasons are pronounced enough that trees are either deciduous or xerophytic. Many of these soils have or have had savanna vegetation, and some were grasslands. Most of the soils are used as cropland or for grazing. Some are used as irrigated cropland. Sorghum, wheat, and cotton are the most common crops. Droughts are common.

Ustalfs tend to form a belt between the Aridisols of arid regions and the Udalfs, Ultisols, Oxisols, and Inceptisols of humid regions. Ustalfs are extensive in the world, occurring in North America, South America, Africa, Australia, and Asia. In the United States, they generally are moderate in extent but are extensive in the southern part of the Great Plains.

Ustalfs may be in areas of erosional surfaces or deposits of late-Wisconsinan age, but a great many, and characteristically those of warm regions, are on old surfaces. In the Ustalfs on old surfaces, the minerals have been strongly weathered, possibly in an environment more humid than the present one. The clays in many of these older soils are kaolinitic. Their base saturation at present probably reflects additions of bases from dust and rain.


Ustalfs
Durustalfs
Plinthustalfs
Natrustalfs
Kandiustalfs
Kanhaplustalfs
Paleustalfs
Rhodustalfs
Haplustalfs



Profile of an Ustalf (specifically a Paleustalf) in Botswana. The soil has a thick clayey argillic horizon beginning at a depth of about 10 cm and extending beyond the base of the photo. Scale is in 10-cm increments.

Return to Ustalfs

Key to Great Groups of Ustalfs (Back to key to suborders)

Ustalfs that have:

1. **A duripan (layer cemented by silica) within a depth of 100 cm --- Durustalfs**
   Begin measuring depth below any O horizon.

2. **Plinthite making up ≥ 50% of a layer within a depth of 150 cm -- Plinthustalfs**
   Begin measuring depth below any O horizon. Plinthite is a firm, iron oxide-rich mass that irreversibly hardens after exposure to repeated wet-dry cycles.

3. **A natric (high levels of illuvial clay and sodium) horizon -- Natrustalfs**

4. **A kandic (very low cation-exchange capacity) horizon in which clay content does not decrease significantly within a depth of 150 cm -- Kandiustalfs**
   Clay content must not decrease by ≥ 20% of the maximum in the kandic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below. Kandiustalfs cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

5. **A kandic (very low cation-exchange capacity) horizon with a significant decrease in clay content within a depth of 150 cm --- Kanhaplustalfs**

6. **Either:**

   a) A petrocalcic (cemented by calcium carbonate) horizon within a depth of 150 cm, OR

   b) An argillic (clay accumulation) horizon in which the clay content does not decrease significantly within a depth of 150 cm and that has hue of 7.5YR in some part of the lower half (and no root-limiting layer within a depth of 150 cm), OR

   c) An abrupt increase in clay content to an argillic horizon with clayey texture (and no root-limiting layer within a depth of 50 cm) --- Paleustalfs
   Begin measuring depth below any O horizon. See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding colors (item b above) and clay increase (item c above). For item b, clay content must not decrease

by ≥ 20% of the maximum in the argillic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below.

7. **An argillic (clay accumulation) horizon with dominantly dark red colors --- Rhodustalfs**
   Specifically, hue is 2.5YR or 10R and value is ≤ 3 moist (and < 1 unit of change dry). Colors make up > 50% and are required throughout the upper 100 cm of the argillic horizon, or the entire argillic if < 100 cm thick.

8. **An argillic (clay accumulation) subsoil horizon with a significant decrease in clay content within a depth of 150 cm ----------- Haplustalfs**

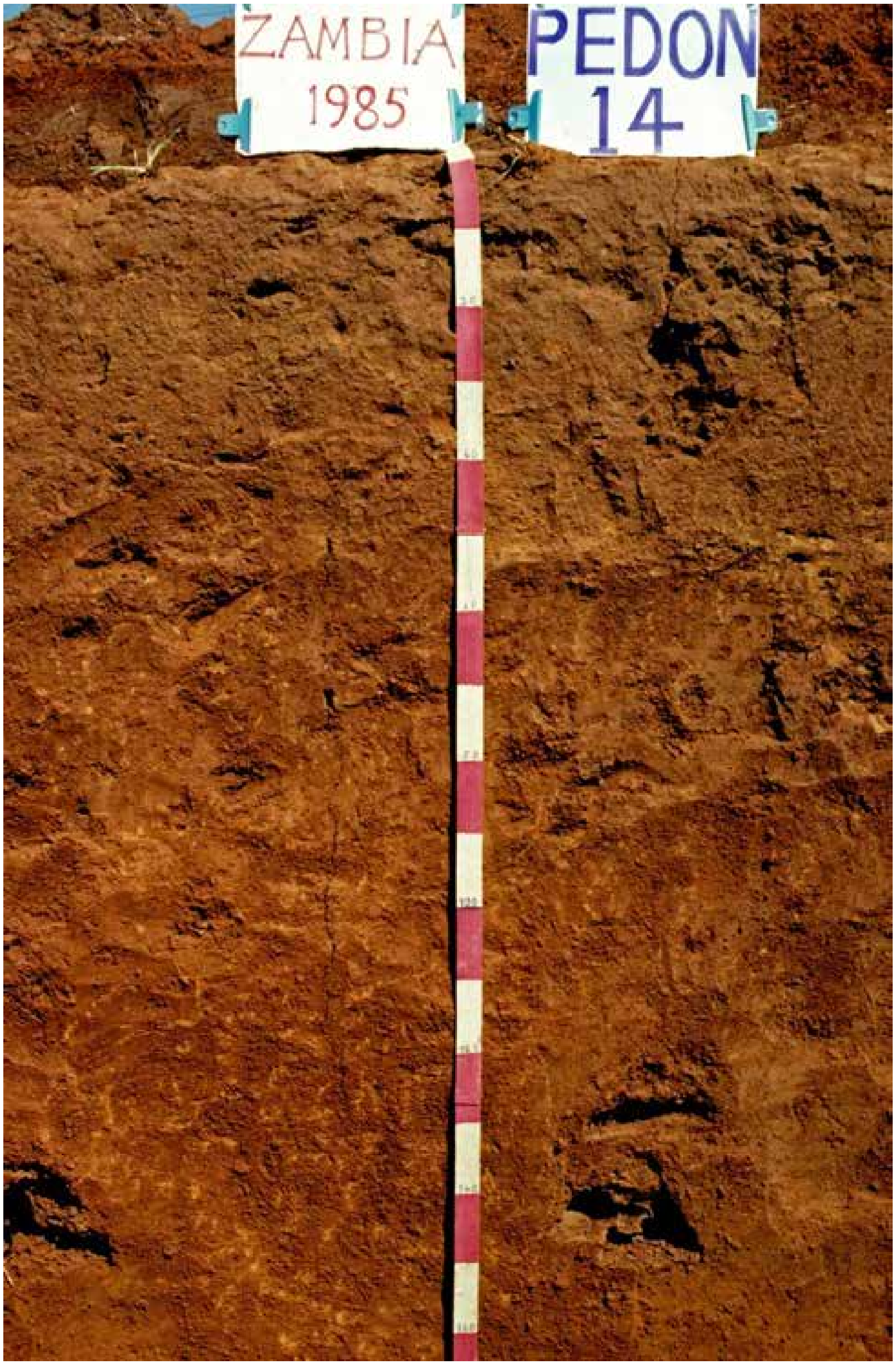
Descriptions of Great Groups of Ustalfs

Durustalfs—These soils have a duripan (layer cemented by silica) that has its upper boundary within 100 cm of the mineral soil surface. They are not known to occur in the United States, but the great group has been provided for use in other countries. (Back to Ustalfs key)

Plinthustalfs—These soils have one or more horizons within 150 cm of the mineral soil surface in which plinthite (firm, iron oxide-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles) either forms a continuous phase or constitutes one-half or more of the volume. There are no soil series in the United States that are presently classified in this great group, but the group is provided for use in other parts of the world. (Back to Ustalfs key)

Natrustalfs—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon. The epipedon is typically 10 to 20 cm thick. The natric horizon generally is underlain by a layer with calcium carbonate accumulations at a depth between about 25 and 40 cm. Except in a few areas of the Great Plains and mountain basins, Natrustalfs are not extensive in the United States. (Back to Ustalfs key)

Kandiustalfs—These soils have thick kandic subsoil horizons that have relatively high base saturation but a low cation-exchange capacity. Many of these soils occur on the older surfaces in warm, humid or semihumid areas. Kandiustalfs occur mostly in Africa and South America. They are commonly used as rangeland or cropland. (Back to Ustalfs key)

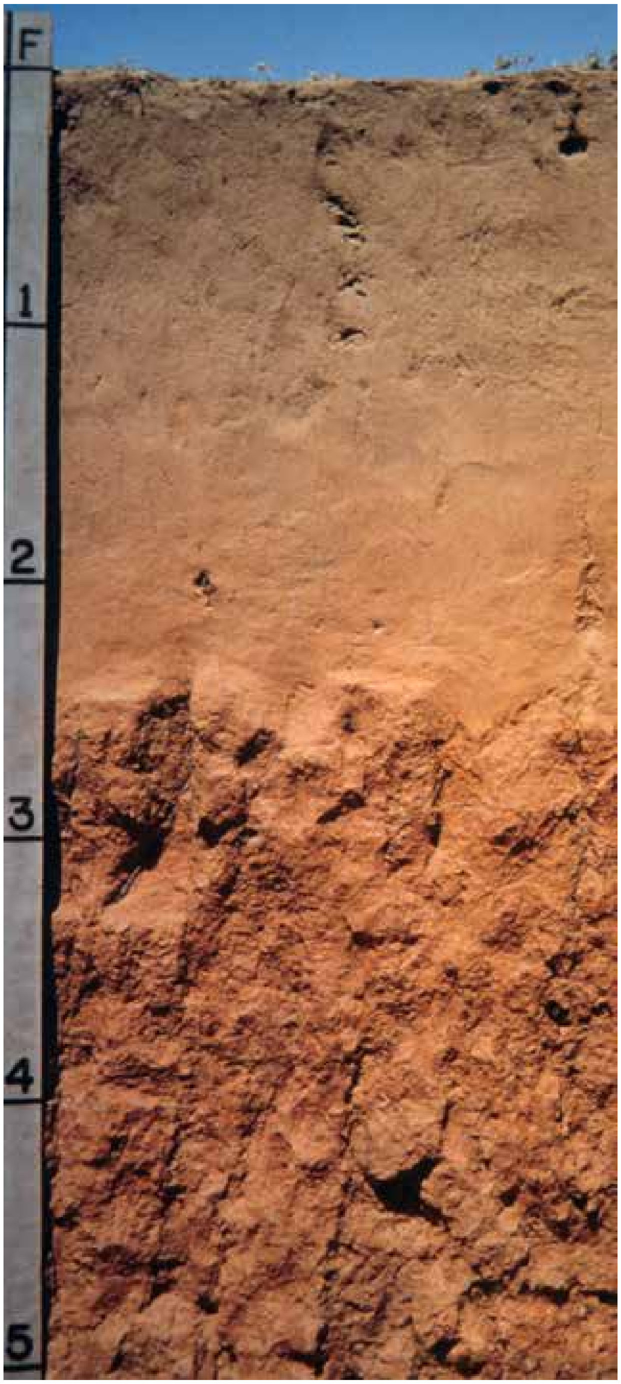


Profile of a well drained, loamy Kandiustalf in Zambia. The intensely weathered kandic horizon (beginning at a depth of about 15 cm and extending below the base of the photo) has low natural fertility and a limited ability to supply plant nutrients. Scale is in 10-cm increments.

Back to Kandiustalfs

Kanhaplustalfs—These soils have relatively high base saturation but have a low cation-exchange capacity. They have a thin to moderately thick kandic subsoil horizon. Kanhaplustalfs commonly occur on the older surfaces in warm, humid or semihumid areas. They are used for livestock grazing or crop production. (Back to Ustalfs key)

Paleustalfs—These are the reddish or red Ustalfs that are on old surfaces. Many of them have some plinthite (iron-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles) in their lower horizons. Paleustalfs occur in relatively stable landscape positions, their slopes are mostly gentle, and their genesis began before the late Pleistocene. In the United States, they typically have a horizon with accumulations of calcium carbonate in or below the argillic horizon as a result of additions of atmospheric carbonates. Secondary lime commonly coats the surfaces of peds that have noncalcareous interiors, and the soils may be noncalcareous at a depth of less than 200 cm. A few of these soils, near the boundary where they join Aridisols, have received enough calcareous dust to have a petrocalcic (cemented by calcium carbonate) horizon. A few others, near the boundary where they join Udults or Udalfs, do not have accumulated carbonates. Before cultivation, the vegetation on the Paleustalfs in the United States included a mixture of grasses and woody plants. These soils are moderately extensive in the southern part of the Great Plains in the United States, and they probably are extensive in Africa and southern Asia. (Back to Ustalfs key)

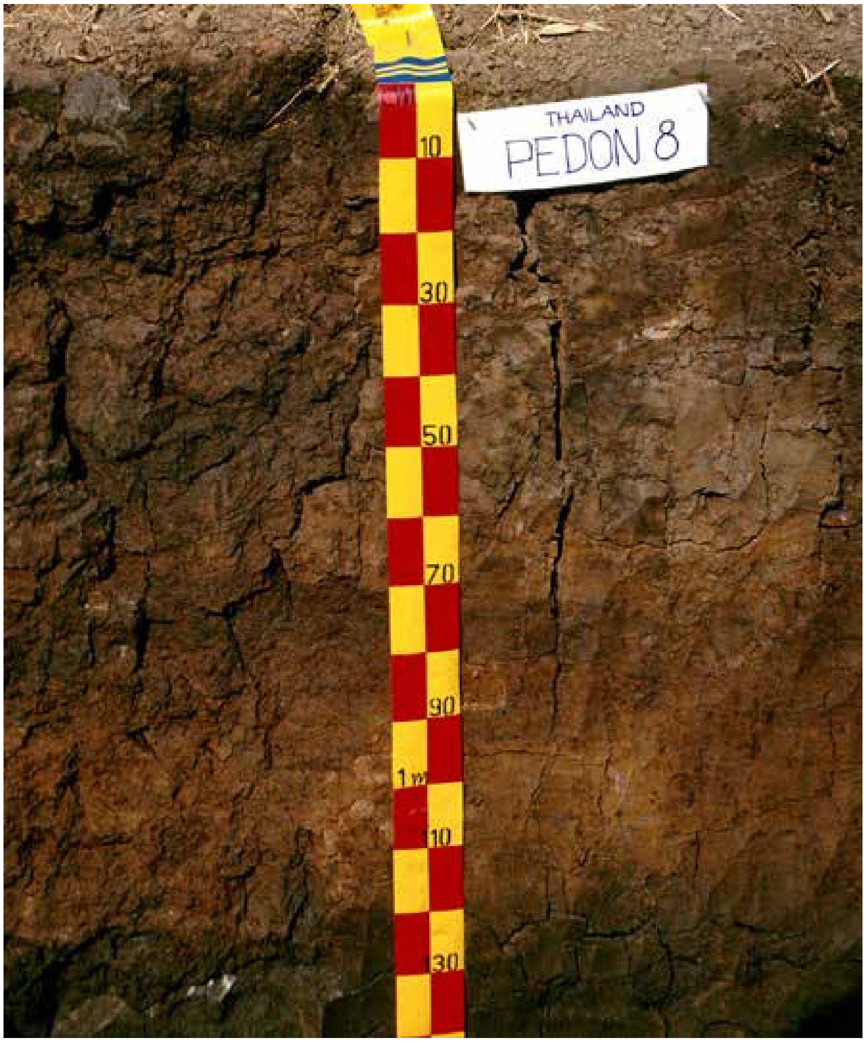


Profile of a well drained Paleustalf in the southwestern United States. The upper 30 inches is light brown fine sand derived from windblown material. An argillic horizon of red and yellowish red sandy clay loam begins at a depth of about 30 inches and extends beyond the base of the photo.

Back to Paleustalfs

Rhodustalfs—These soils have dark red colors and a solum that is thinner than that of the Paleustalfs. Rhodustalfs generally formed on erosional surfaces or in deposits of late-Pleistocene age. In the United States, the vegetation was mostly grass and scattered woody shrubs and trees before the soils were cultivated. The parent materials are basic. These soils are rare in the United States. (Back to Ustalfs key)

Haplustalfs—These soils have a relatively thin argillic (clay accumulation) subsoil horizon. Many of these soils are relatively thin, are reddish to yellowish brown, or have a significant decrease in clay content within a depth of 150 cm. Haplustalfs are commonly in areas of relatively recent erosional surfaces or deposits, most of them late Pleistocene in age. Some of the soils have a monsoon climate. Others have two more or less marked dry seasons during the year. (Back to Ustalfs key)



Profile of a Haplustalf in Thailand. This particular soil has a fairly high content of smectitic clay, causing it to noticeably shrink and crack when dry and to swell when wet. Notice the prominent cracking, especially in the upper 90 cm. Scale is in cm.

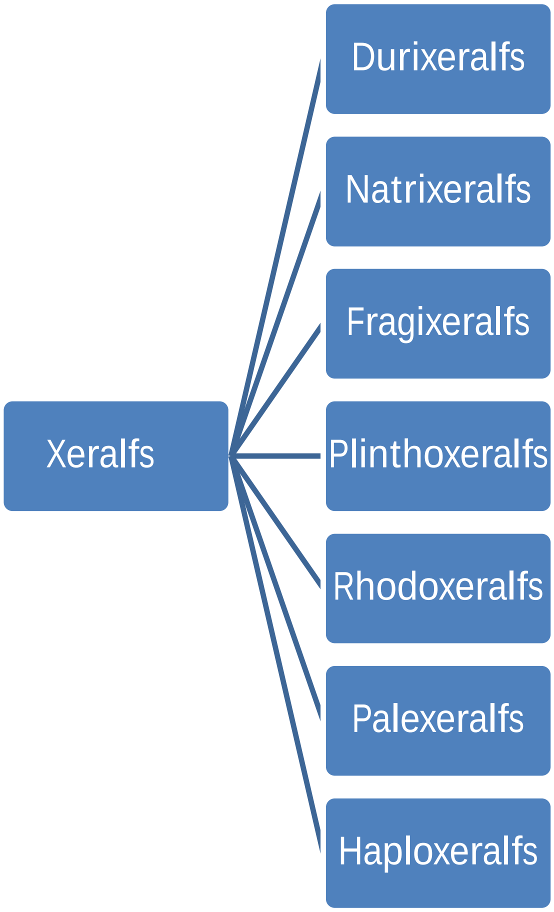
Back to Haplustalfs

Xeralfs Great Groups

Xeralfs are the Alfisols in regions that have a Mediterranean-type climate. As their name implies, they have a xeric moisture regime. They are dry for extended periods in summer. In winter in some years, however, moisture moves through the soil to deeper layers. Small grain and other winter annuals are common crops in nonirrigated areas of Xeralfs. Grapes and olives also are common crops where the climate is thermic. With irrigation, a wide variety of crops can be grown.

Xeralfs formed not only in the area around the Mediterranean Sea but also in parts of South Africa, Chile, western and southern Australia, and western United States. The temperature regime is cold to warm. Although Xeralfs are not very extensive worldwide, in some local regions they are dominant. In the United States, they are moderately extensive in some areas. In areas of the warmest and driest Xeralfs, the vegetation before the soils were farmed was a mixture of annual grasses, forbs, and woody shrubs. In areas of the coolest and moistest Xeralfs, it was coniferous forest.

Xeralfs formed on surfaces of different ages. Some formed on erosional surfaces or in deposits of late-Wisconsinan age. Some, such as those in Australia, are on old surfaces and have characteristics that probably reflect an environment greatly different from the present one. In the oldest Xeralfs, the boundary between the surface and subsoil horizons commonly is very abrupt. The epipedon of some Xeralfs is hard and massive when dry.


Xeralfs
Durixeralfs
Natrixeralfs
Fragixeralfs
Plinthoxeralfs
Rhodoxeralfs
Palexeralfs
Haploxeralfs

Profile of a Xeralf (specifically a Haploxeralf) in California. This soil has a paralithic contact below a depth of about 40 inches. Scale is in inches.

Key to Great Groups of Xeralfs (Back to key to suborders)

Xeralfs that have:

1. **A duripan (layer cemented by silica) within a depth of 100 cm --- Durixeralfs**
   Begin measuring depth below any O horizon.

2. **A natric (high levels of illuvial clay and sodium) horizon --- Natrixeralfs**

3. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm -- Fragixeralfs**
   Begin measuring depth below any O horizon.

4. **Plinthite making up ≥ 50% of a layer within a depth of 150 cm -- Plinthoxeralfs**
   Begin measuring depth below any O horizon. Plinthite is a firm, iron oxide-rich mass that irreversibly hardens after exposure to repeated wet-dry cycles.

5. **An argillic (clay accumulation) or kandic (very low cation-exchange capacity) horizon with dominantly dark red colors ------- Rhodoxeralfs**
   Specifically, hue is 2.5YR or 10R and value is ≤ 3 moist (and < 1 unit of change dry). Colors make up > 50% and are required throughout upper 100 cm of an argillic or kandic horizon, or the entire argillic or kandic if < 100 cm thick.

6. **Either:**

   a) A petrocalcic (cemented by calcium carbonate) horizon within a depth of 150 cm, OR

   b) An argillic (clay accumulation) or kandic (very low cation-exchange capacity) horizon that extends to ≥ 150 cm and a clay content that does not decrease significantly within a depth of 150 cm, OR

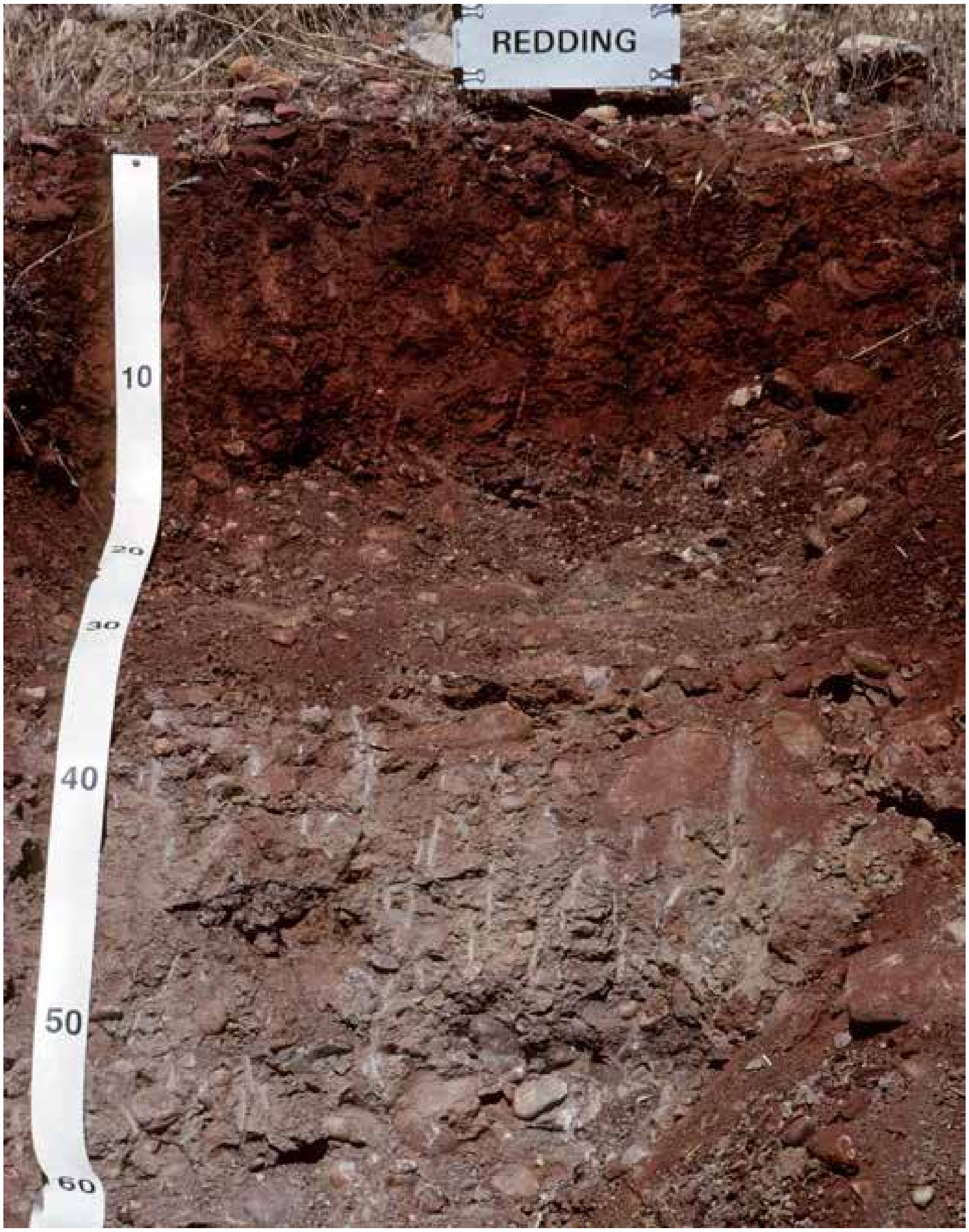
   c) An abrupt increase in clay content to an argillic (clay accumulation) or kandic (very low cation-exchange capacity) horizon with clayey texture (and no root-limiting layer within a depth of 50 cm) -- Palexeralfs
   Begin measuring depth below any O horizon. For item b, clay content must not decrease by ≥ 20% of the maximum in the argillic or kandic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below. See 12th edition of

“Keys to Soil Taxonomy” for specific criteria regarding an abrupt clay increase (item c above).

7. **An argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon -- Haploxeralfs**

Descriptions of Great Groups of Xeralfs

Durixeralfs—These soils have a duripan (layer cemented by silica) that has an upper boundary within a depth of 100 cm but below an argillic (clay accumulation) or natric (high levels of illuvial clay and sodium) horizon. These soils are known to have formed in California, Idaho, Nevada, Oregon, Chile, and Italy, in areas of Pleistocene or earlier volcanism. Some of the Durixeralfs in the United States appear to be on very old surfaces and have complex horizons that indicate polygenesis. The oldest soils are commonly reddish and have kaolinitic mineralogy. Other Durixeralfs appear to have formed in late-Pleistocene sediments and are yellowish brown and have less weathered clays. The duripan commonly has an upper boundary about 50 cm below the soil surface and has very coarse polyhedrons, the tops and sides of which are coated with opal or chalcedony. In undisturbed areas of Durixeralfs in the United States, a microrelief of about 10 to 100 cm or more is common. The microrelief is mainly the result of differences in the thickness of horizons that are above the duripan. In the United States, Durixeralfs are moderately extensive only in California and Idaho. (Back to Xeralfs key)



Profile of a Durixeralf in California. The reddish, clayey argillic horizon extends to a depth of about 20 inches. Below 20 inches is a silica-cemented duripan, which extends to below the base of the photo. Scale is in inches.

Back to Durixeralfs

Natrixeralfs—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon. They are not extensive. They support sparse vegetation that commonly consists of salt-tolerant grasses and forbs. (Back to Xeralfs key)

Fragixeralfs—These soils have a fragipan (firm and brittle but not cemented layer) with an upper boundary within a depth of 100 cm. Commonly, these soils have a brown argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon, a gray and red mottled color pattern (redoximorphic features), and a perched water table that is seasonally above the pan. Above the pan, some Fragixeralfs have a thin eluvial horizon with peds that have gray clay depletions. Most Fragixeralfs in the United States are on gentle or moderate slopes and formed, at least in part, in silty or loamy late-Pleistocene deposits. Some are strongly sloping. Temperature regimes are mesic or frigid. In the United States, the native vegetation is primarily coniferous forest. Fragixeralfs are of small extent in Idaho and Oregon. (Back to Xeralfs key)

Plinthoxeralfs—These soils have one or more horizons within 150 cm of the mineral soil surface in which plinthite (firm, iron oxide-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles) either forms a continuous phase or constitutes one-half or more of the volume. There are few areas of these soils in the United States, but the soils are moderately extensive in other parts of the world. (Back to Xeralfs key)

Rhodoxeralfs—These are the more or less dark red Xeralfs that formed in areas of limestone, basalt, and other highly basic parent materials. As a group, these soils are remarkably uniform in virtually all properties, except depth to bedrock. A few that receive carbonates may have a calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon below the argillic (clay accumulation) or kandic (very low cation-exchange capacity) horizon. Rhodoxeralfs are rare in the United States. (Back to Xeralfs key)

Palexeralfs—These soils have a petrocalcic (cemented by calcium carbonate) subsoil horizon or an argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon that is thick or that has, at its upper boundary, both a clayey texture and a large increase in clay content. Many of these soils have some plinthite (firm, iron oxide-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles) in their lower horizons, but this feature is rare in the United States. Palexeralfs are in relatively stable landscape positions on gentle slopes, and most began their genesis before the late Pleistocene. During pluvial periods of the Pleistocene, carbonates appear to have been almost completely removed from the argillic or kandic horizon of most of these soils, but some of the soils appear to have been recalcified later. Most Palexeralfs formed in acid or in moderately basic parent materials, but some formed in materials as basic as basalt. The native vegetation on the warmest Palexeralfs in the United States was a mixture of annual grasses, forbs, and woody shrubs. The native vegetation on the coolest Palexeralfs was mostly a coniferous forest. Palexeralfs are moderately extensive in the United States as well as in other parts of the world. (Back to Xeralfs key)

Profile of a Palexeralf in Victoria, Australia. Clay has been leached from the upper 15 to 25 cm, resulting in a loamy, predominantly gray horizon with a wavy lower boundary. Below this is a thick, reddish, clay-enriched argillic horizon that extends below the base of the photo.

Back to Palexeralfs

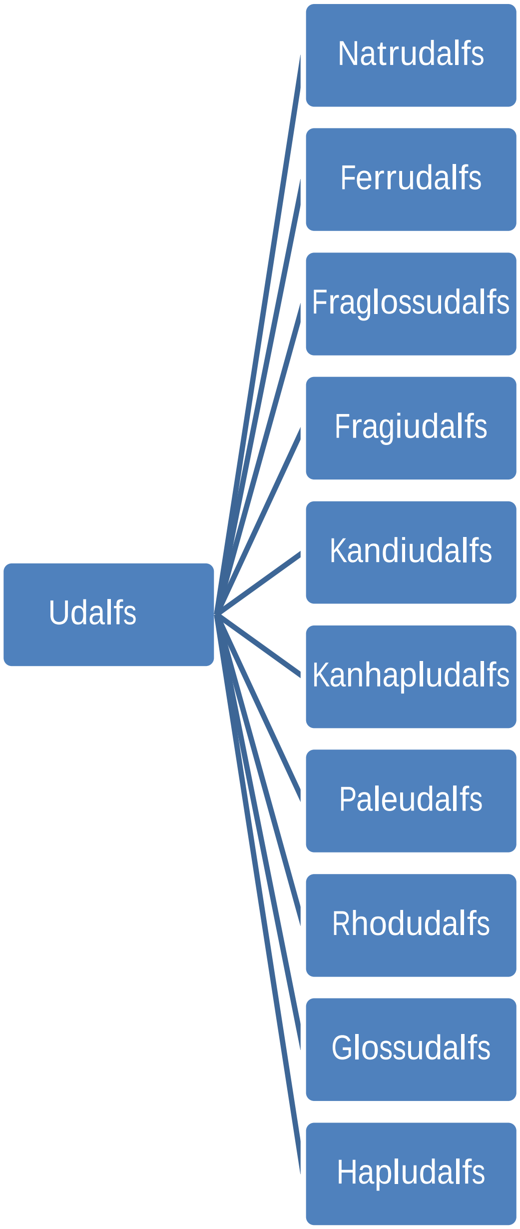
Haploxeralfs—These soils have an argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon that is relatively thin, has a clear or gradual upper boundary, or has a loamy particle-size class throughout. Many Haploxeralfs formed in late-Pleistocene deposits or on erosional surfaces of that age. Their parent materials may be either acidic or basic. These soils are extensive in the areas of Xeralfs in the western United States. (Back to Xeralfs key)

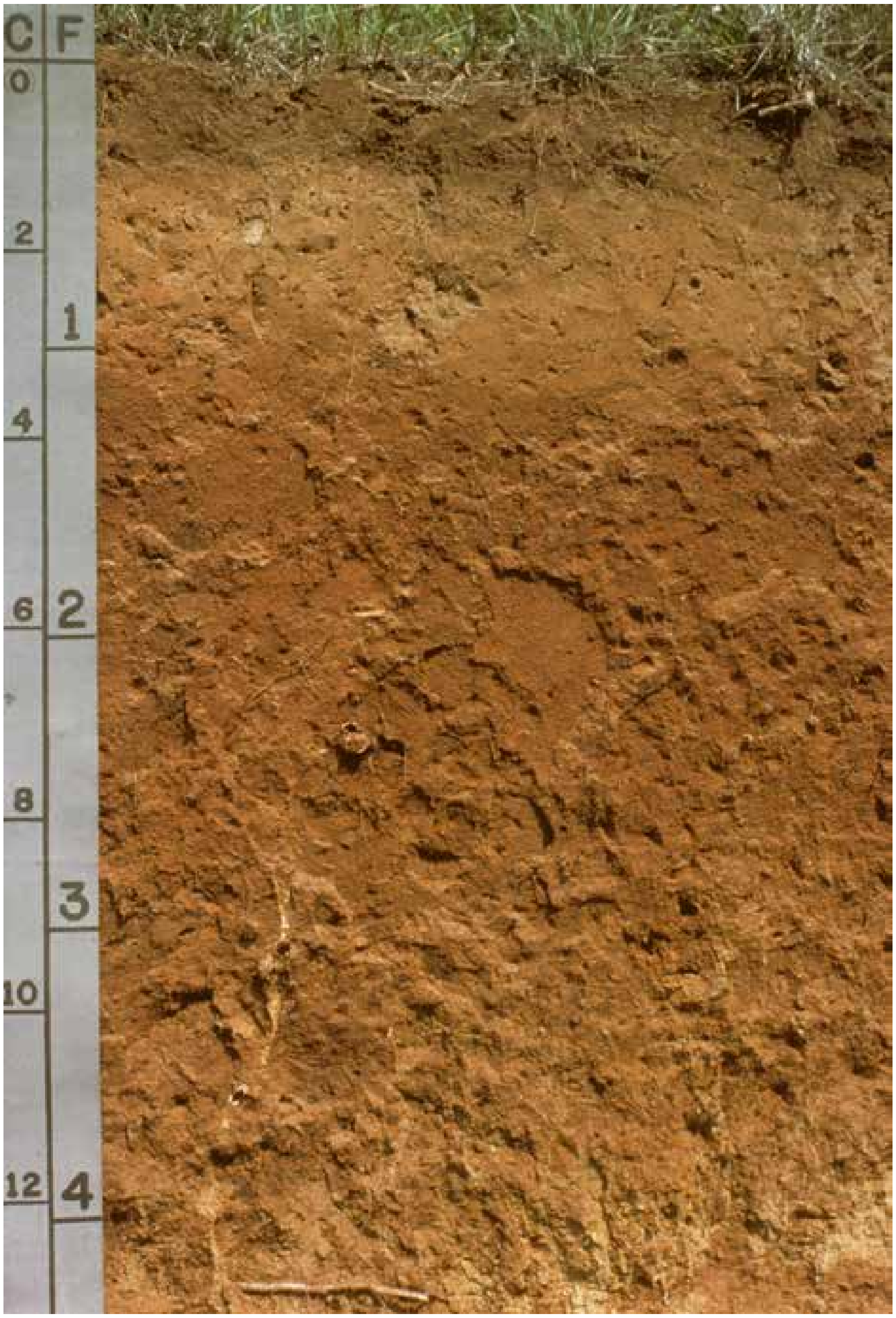
Udalfs Great Groups

Udalfs are the more or less freely drained Alfisols that have seasonally well-distributed precipitation (udic moisture regime) and cold to warm temperature regimes. These soils are principally but not entirely in areas of late-Pleistocene deposits and erosional surfaces of about the same age. Some of the Udalfs that are on the older surfaces are underlain by limestone or other calcareous sediments.

Udalfs are very extensive in the United States and Western Europe. All of them are believed to have supported forest vegetation at some time during development. Most Udalfs with a mesic or warmer temperature regime have or had deciduous forest vegetation, and many with a frigid temperature regime have or had mixed coniferous and deciduous forest vegetation.

Many Udalfs have been cleared of trees and are intensively farmed. As a result of erosion, many now have subsoil material exposed at the surface and incorporated into plow layers. Other Udalfs are on stable surfaces and retain most of their original surface layers. Normally, the undisturbed soils have a thin surface layer darkened by humus. A few Udalfs have a natric (high levels of illuvial clay and sodium) horizon. Others have a fragipan (firm and brittle but not cemented layer).


Natrudalfs
Ferrudalfs
Fraglossudalfs
Fragiudalfs
Kandiudalfs
Udalfs
Kanhapludalfs
Paleudalfs
Rhodudalfs
Glossudalfs
Hapludalfs



Profile of a Udalf (specifically a Hapludalf). Note the light-colored E horizon that extends to a depth of about 10 inches. Clay content of the argillic horizon decreases noticeably below a depth of about 3 feet.

(Back to Udalfs)

Key to Great Groups of Udalfs (Back to key to suborders)

Udalfs that have:

1. **A natric (high levels of illuvial clay and sodium) horizon -- Natrudalfs**

2. **Both:**

   a) A glossic (degraded argillic) horizon AND

   b) Iron-enriched nodules in the subsoil --------------------------- Ferrudalfs
   The nodules are 2.5-30 cm in diameter, have some degree of cementation (at least an extremely weak class), and have exteriors that have redder hue or higher chroma as compared to interiors.

3. **Both:**

   a) A glossic (degraded argillic) horizon AND

   b) A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm --- Fraglossudalfs
   Begin measuring depth below any O horizon.

4. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm -- Fragiudalfs**
   Begin measuring depth below any O horizon.

5. **A kandic (very low cation-exchange capacity) horizon in which clay content does not decrease significantly within a depth of 150 cm --- Kandiudalfs**
   Clay content must not decrease by $\geq$ 20% of the maximum in the kandic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by $\geq$ 3% below. Kandiudalfs cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

6. **A kandic (very low cation-exchange capacity) horizon with a significant decrease in clay content within a depth of 150 cm -- Kanhapludalfs**

7. **All:**

   a) No root-limiting layer within a depth of 150 cm, AND

   b) A clay content that does not decrease significantly within a depth of 150 cm, AND

   c) Either an argillic (clay accumulation) horizon with hue or 7.5YR or redder colors in at least part OR, if the temperature regime is frigid, an argillic horizon (any color) that is overlain by a glossic (degraded argillic) horizon -- Paleudalfs
   For items a and b, begin measuring depth below any O horizon. Clay content must not decrease by ≥ 20% of the maximum in the argillic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding required colors for the argillic horizon (item c). For frigid soils (item c) begin measuring below any O horizon or mantle with vitric volcanic materials, if present. Some layer above the argillic horizon must have texture finer than loamy fine sand. The glossic criterion is waved if there is interfingering of albic materials into the argillic horizon.

8. **An argillic (clay accumulation) horizon with dominantly dark red colors -- Rhodudalfs**
   Specifically, hue is 2.5YR or 10R and value is ≤ 3 moist (and < 1 unit of change dry). Colors make up > 50% and are required throughout upper 100 cm of argillic horizon, or the entire argillic horizon if < 100 cm thick.

9. **A glossic (degraded argillic) horizon ---------------------------- Glossudalfs**

10. **An argillic (clay accumulation) horizon with a significant decrease in clay content within a depth of 150 cm ---------------------------- Hapludalfs**

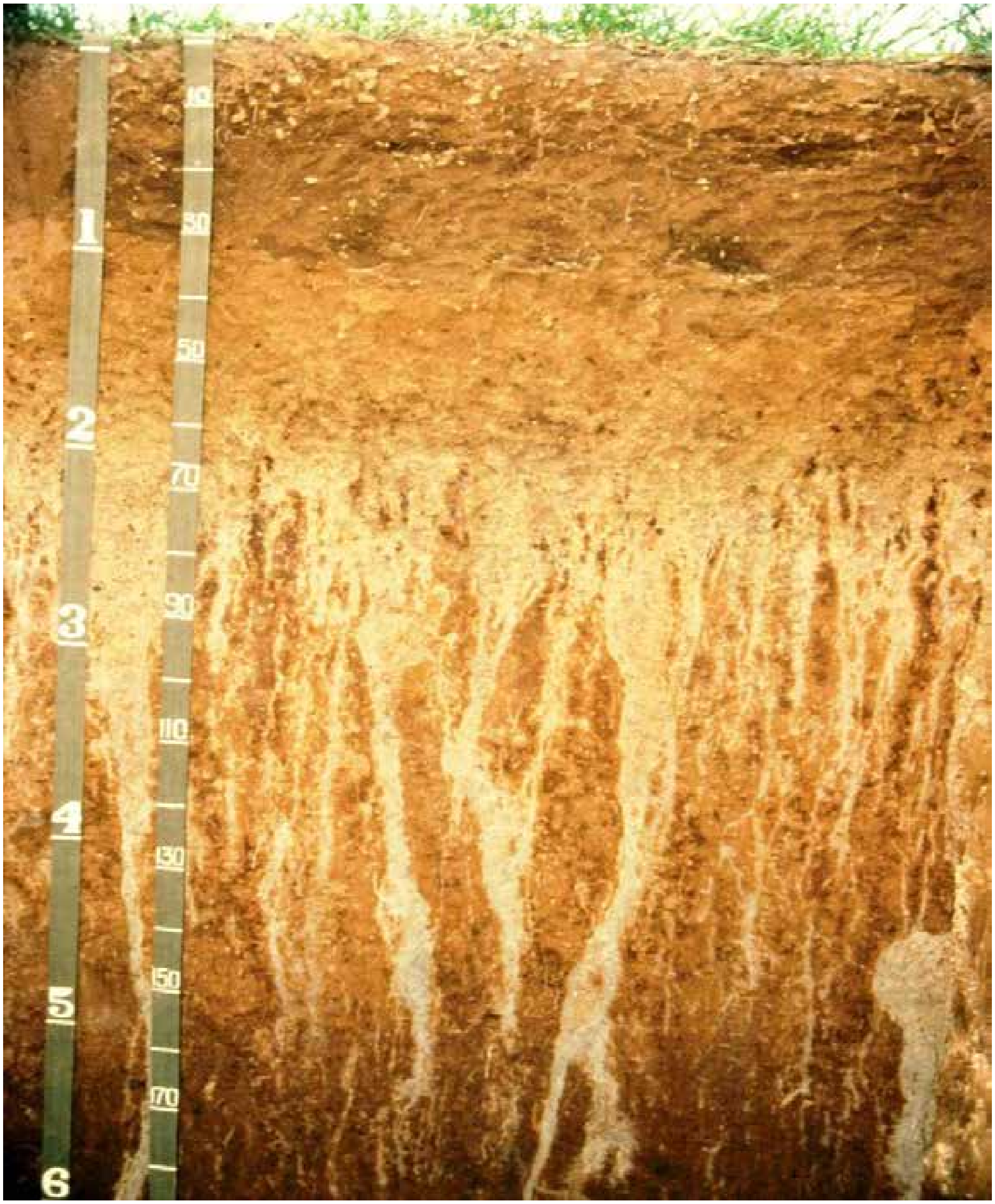
Descriptions of Great Groups of Udalfs

Natrudalfs—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon. Because the natric horizon is slowly permeable, perched ground water is common for short periods and the natric horizon commonly has redoximorphic features. Some of the soils were forested. Some supported open forests, and some supported grass. Most of the soils have been cleared and are used as cropland or pasture. These soils are not as productive as most Udalfs, but they generally are farmed if they occur in very small areas and if the associated soils are productive. These soils are of small extent in the United States. (Back to Udalfs key)

Ferrudalfs—These soils have both a glossic (degraded argillic) subsoil horizon and an argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon that has been partially cemented by iron. In some areas, these soils formed under heath vegetation. The heath vegetation may have succeeded a forest following many years of collection and removal of forest litter. Under the heath, which is efficient in complexing iron and aluminum, the upper part of the argillic horizon was destroyed and fragments of this horizon became coated and weakly cemented with iron. Some Ferrudalfs have a fragipan (firm and brittle but not cemented layer) at some depth, commonly about 100 cm. Ferrudalfs are not known to occur in the United States and are rare elsewhere. (Back to Udalfs key)

Fraglossudalfs—These soils have both a fragipan (firm and brittle but not cemented layer) within a depth of 100 cm and a glossic (degraded argillic) subsoil horizon. They are not extensive in the United States. They are more extensive in Europe. (Back to Udalfs key)

Fragiudalfs—These soils have a fragipan (firm and brittle but not cemented layer) within a depth of 100 cm. They commonly have an argillic (clay accumulation) or cambic (minimal soil development) subsoil horizon above the fragipan. Redoximorphic features (gray and red mottled color pattern) are in many pedons, starting at a depth 50 to 100 cm. Ground water is perched seasonally above the fragipan, and a thin eluvial horizon commonly is directly above the fragipan. Most Fragiudalfs in the United States are on gentle slopes and formed, at least in part, in silty or loamy deposits. The deposits are largely of late-Pleistocene age. The fragipan formed in an older buried soil in some areas. A fragipan seems to form if the burial was to a depth of about 50 to 75 cm. Temperature regimes are mostly cold to warm. In the United States, the native vegetation on these soils was primarily a broadleaf deciduous forest.
(Back to Udalfs key)



Profile a Fragiudalf in Tennessee. This soil has a firm, dense, fragipan with prismatic structure below a depth of about 60 cm. The gray vertical penetrations of soil material consist of friable, eluvial silt coatings surrounding the browner, clay-enriched soil material of the dense prism interiors. Percolating water tends to move downward through the gray seams. Scale is in feet (left) and centimeters (right).

Back to Fragiudalfs

Kandiudalfs—These soils have a thick kandic (very low cation-exchange capacity) subsoil horizon in which the content of clay does not decrease significantly from its maximum within a depth of 150 cm. These soils are 150 cm or more deep to any root-limiting layer, such as a densic, lithic, paralithic, or petroferric contact. The base of the kandic horizon is commonly more than 150 cm below the soil surface and in some areas is more than 200 cm below. Most of these soils have a thermic or warmer soil temperature regime. The natural vegetation was forest, mostly deciduous, but many of the soils are now cleared and used as cropland. (Back to Udalfs key)

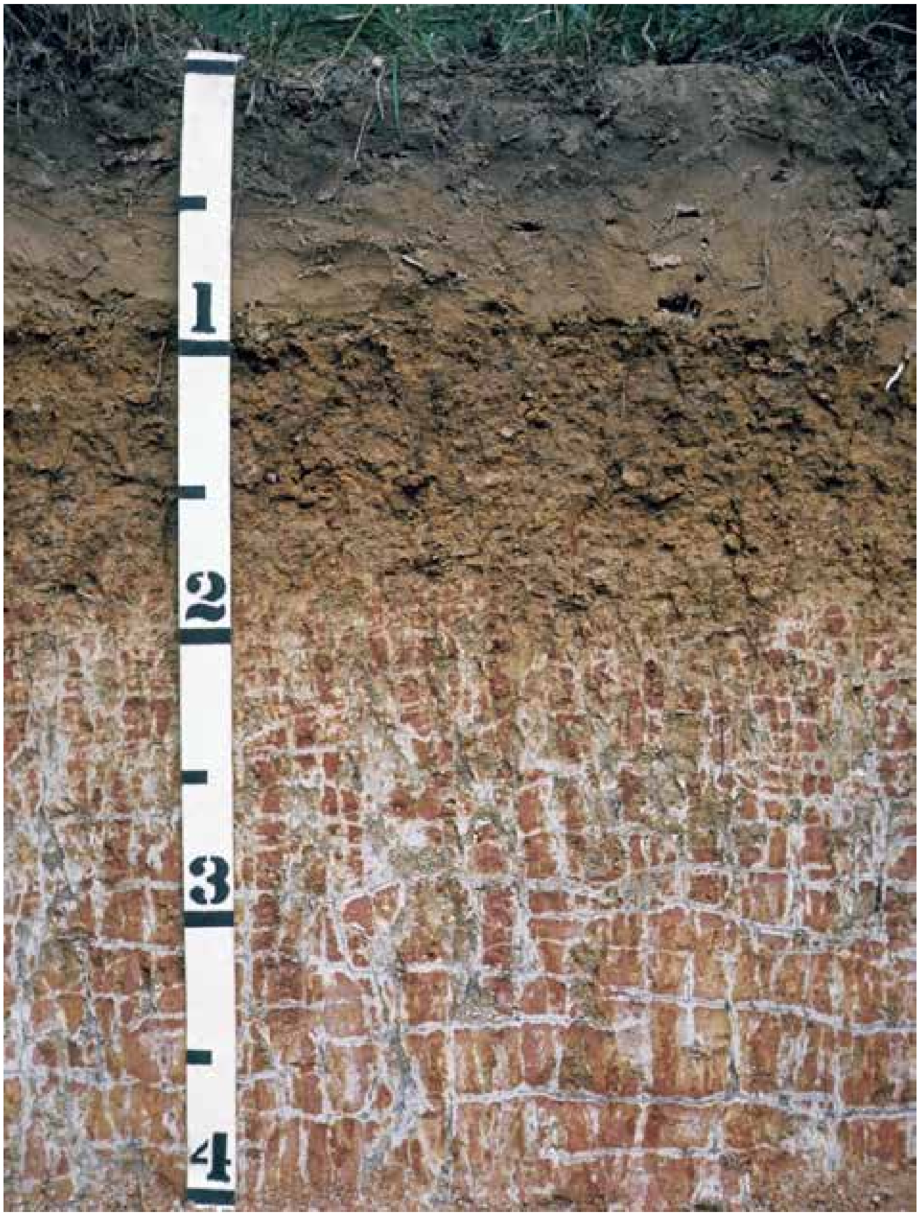
Kanhapludalfs—These soils have a kandic (very low cation-exchange capacity) subsoil horizon in which the content of clay decreases significantly from its maximum amount within a depth of 150 cm. Most of these soils have a thermic or warmer soil temperature regime. The natural vegetation was forest, mostly deciduous, but many of the soils are now cleared and used as cropland. (Back to Udalfs key)

Profile of a Kanhapludalf in Uganda. This soil has a dark ochric epipedon that has a relatively high content of organic matter and extends to a depth of about 30 cm. Below this is a red, clayey kandic subsoil horizon. The subsoil of this particular soil has a high content of small ironstone fragments, locally called "murram." These fragments are used in construction for gravel roads. Scale is in cm.

Return to Kanhapludalfs

Paleudalfs—These soils have a thick solum. Some have an argillic (clay accumulation) subsoil horizon that shows evidence of destruction in the form of a glossic horizon. Paleudalfs are on relatively stable surfaces. Most of them are older than the Wisconsinan Glaciation. The time of soil formation dates from the Sangamon interglacial period or earlier. Base saturation commonly is lower than that in many other Alfisols. Before cultivation, most Paleudalfs in the United States had a vegetation of mixed deciduous hardwood forest.

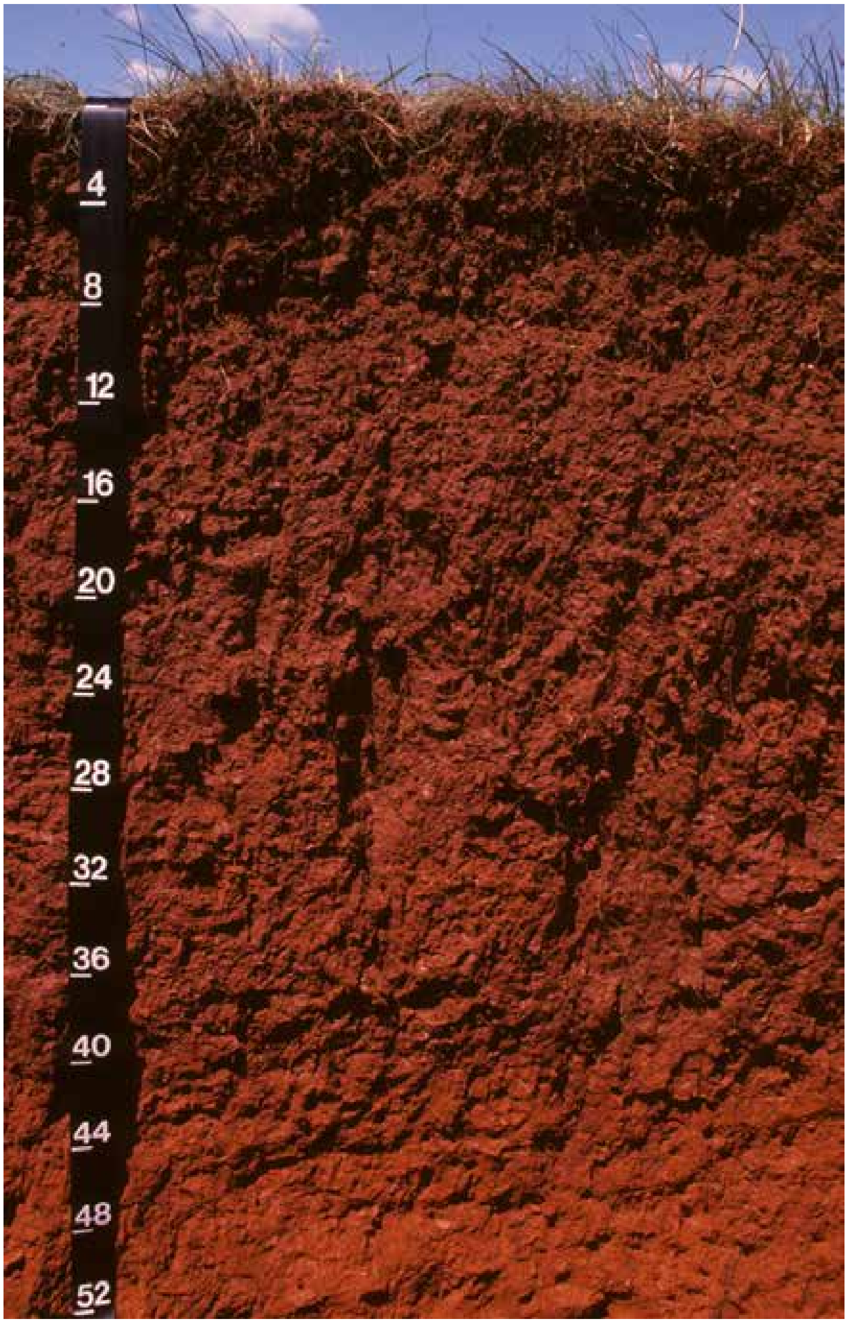
(Back to Udalfs key)



Profile of a Paleudalf in Texas. This soil has an ochric epipedon about 12 inches thick that consists of a dark surface layer about 6 inches thick over a grayish brown horizon from which clay has been leached. An argillic horizon begins at a depth of about 12 inches and extends below the base of the photo. Beginning at about 2 feet, the argillic horizon has red plinthite arranged in a blocky, roughly interlocking pattern that is sometimes referred to as "reticulate mottling." This layer restricts the downward movement of water, which is mostly limited to the gray areas surrounding the plinthite. Scale is in feet.

Return to Paleudalfs

Rhodudalfs—These are the dark red Udalfs that have a solum that is thinner than that of Paleudalfs. Because their parent materials are mostly mafic (high base minerals), they are relatively fertile soils. Rhodudalfs are rare in the United States. (Back to Udalfs key)



Profile of a Rhodudalf with a prominent, dusky red, clay-enriched argillic horizon that begins at a depth of about 4 inches and extends below the base of the photo. The clay content of the argillic horizon decreases noticeably below a depth of about 40 inches. Most Rhodudalfs formed from mafic (base-rich) parent materials and are therefore generally naturally fertile. Scale is in inches.

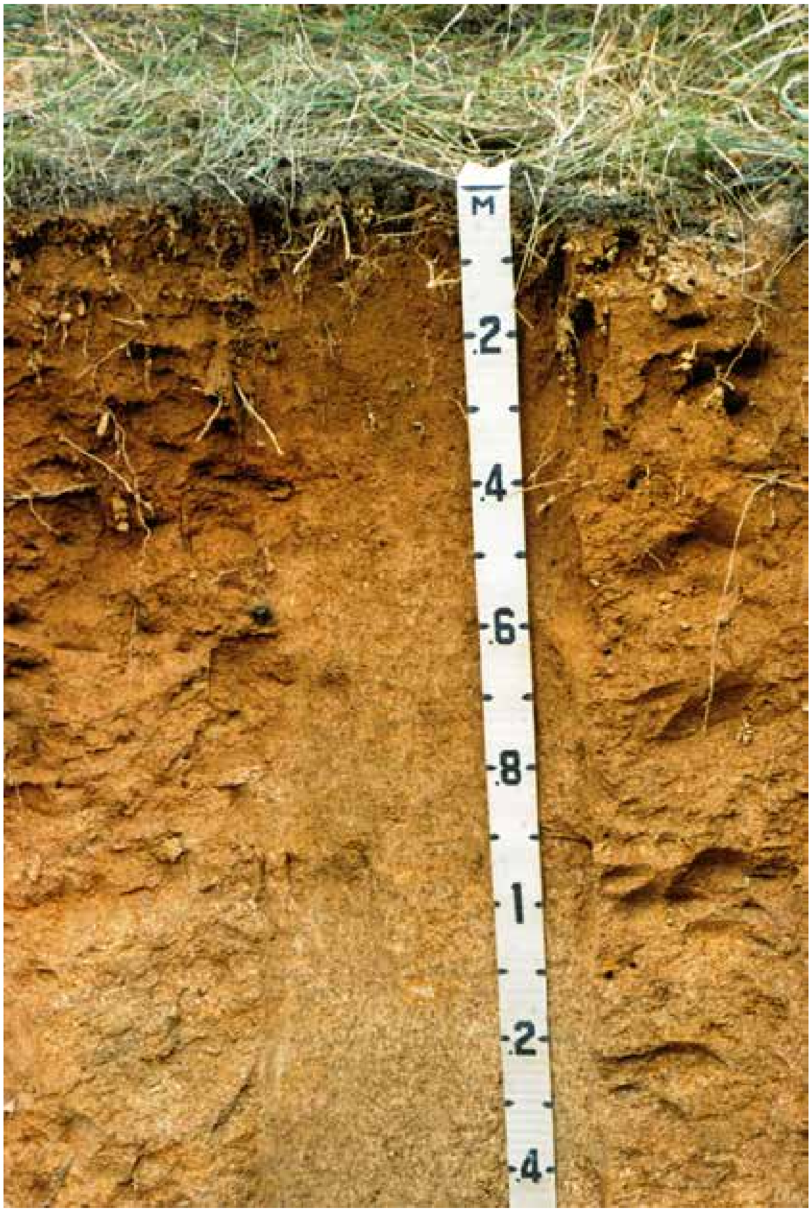
Return to Rhodudalfs

Glossudalfs—These soils have an argillic (clay accumulation) subsoil horizon that shows evidence of destruction in the form of a glossic horizon. The glossic horizon extends through the argillic horizon in some of these soils. Glossudalfs are more extensive in Europe than in the United States. (Back to Udalfs key)

Profile of a Glossudalf in Idaho. The subsoil from depths of about 60 to 150 cm is a glossic horizon with a brown and gray color pattern. The gray areas consist of eluvial material from which a significant amount of clay has been leached. The brown areas are illuvial clay-enriched materials (argillic part of the horizon). This color pattern is easily seen on the lower left side of the photo, where the soil profile has been smoothed. A glossic horizon is thought to be a degrading argillic horizon. Scale is in cm.

Return to Glossudalfs

Hapludalfs—These soils have an argillic (clay accumulation) subsoil horizon that typically extends to a depth of less than 50 cm. In many areas, the argillic horizon is at a depth of less than 100 cm. Where undisturbed, these soils generally have a thin, very dark brown A horizon that is 5 to 10 cm thick, over a lighter-colored brownish eluvial horizon. The eluvial horizon grades into a finer textured argillic horizon, generally at a depth of about 30 to 45 cm in loamy materials. Because these soils have been cultivated extensively, many of those on slopes have lost their eluvial horizons through erosion. Hapludalfs formed principally in late-Pleistocene deposits or on a surface of comparable age. Temperature regimes are mesic or thermic. Hapludalfs are extensive in the northeastern States, excluding New England, and in Europe, excluding most of Scandinavia. In the United States, the vegetation was deciduous broadleaf forest but these soils are now mostly farmed. (Back to Udalfs key)



Profile of a well drained Hapludalf in Korea. This soil has a thin, dark ochric epipedon about 10 cm thick, which is underlain by a clay-enriched argillic horizon extending to a depth of about 90 cm. The argillic horizon is dark yellowish brown in the upper part and becomes progressively lighter with depth. The material below about 90 cm is coarse loamy sand that has weathered in place from granitic bedrock. The right side of the photo has been smoothed; the left side retains the natural soil structure. Scale is in 10-cm increments.

Return to Hapludalfs

Andisols Order

Andisols are relatively young soils, mostly of volcanic origin, and are characterized by unique minerals with poorly organized crystalline structure.

General Characteristics

The key distinguishing characteristic of the Andisols is the presence of andic soil properties within a significant portion of at least the upper 60 cm of the soil. In general, the soils with andic properties are characterized as either: 1) weakly weathered soils with relatively high contents of volcanic glass and only low or moderate amounts of the minerals that result from weathering of the glass, or 2) moderately weathered soils that are rich in short-range order (poorly crystalline) weathering by-products and have lesser amounts of glass remaining. However, Alfisols can have a wide variety of surface and subsoil horizon types.

Environment and Processes

Most Andisols formed in volcanic ejecta, such as volcanic ash, pumice, cinders, and lava. The dominant processes in most Andisols are the weathering and mineral transformation of primary alumino-silicate minerals (commonly glassy) that form short-range-order (poorly crystalline) minerals, such as allophane, imogolite, and ferrihydrite. These short-range-order minerals are responsible for andic soil properties. Some Andisols formed in non-volcanic parent materials. These soils formed in environments with relatively high amounts of soil organic matter, particularly in cool and moist areas. These environments promote the formation of organo-metal compounds, which can also result in andic soil properties.

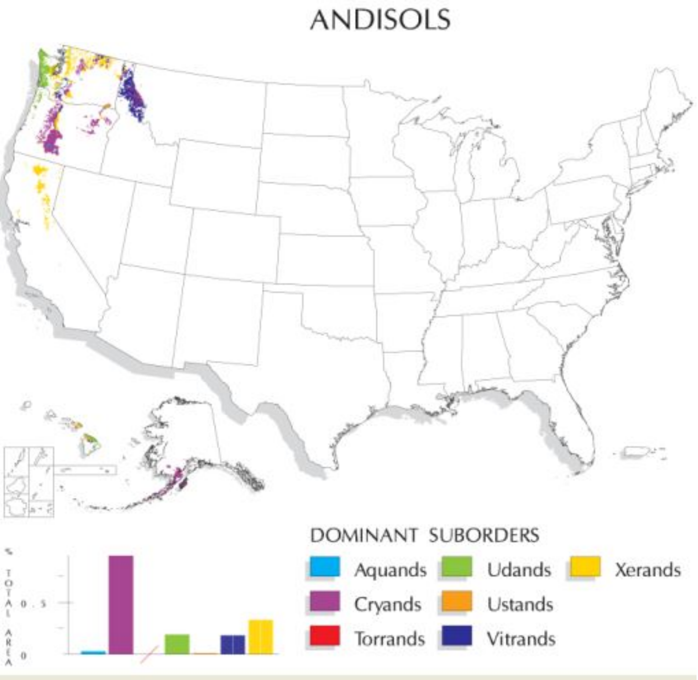
Andisols are generally considered highly productive soils. Their unique mineral constituents typically result in high water-holding capacities. These soils are mostly very friable and have low bulk density. In areas that experience periodic volcanic eruptions, additions of fresh tephra can resupply nutrients and maintain favorable fertility. One negative aspect of the unique mineral make up of Andisols is a propensity to adsorb phosphorus, making it unavailable to plants.

Location

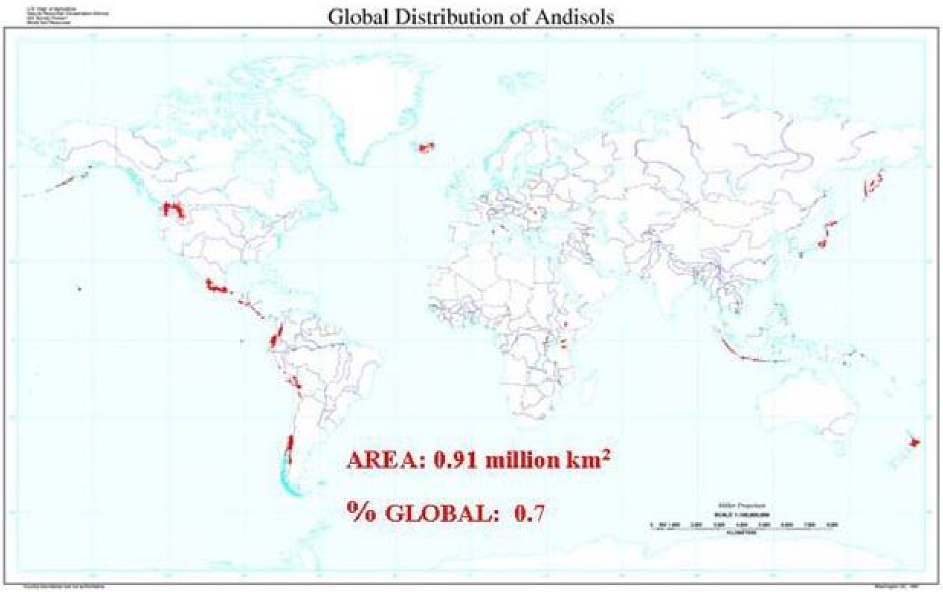
Andisols occur in a wide range of environments. They may have any soil moisture or temperature regime. They can occupy any position on the landscape and can occur at any elevation. Globally, Andisols are the least-extensive soil order and occupy only about 1% of the ice-free land area. They are concentrated along the Pacific Ring of Fire, a zone of active volcanoes that stretches along the western coast of North, Central, and South America; across the Aleutian Islands; along the Russia's east coast; through Japan, the Philippine Islands, and Indonesia; and across Papua New Guinea, the Solomon Islands, and Vanuatu and other Pacific Islands to New Zealand. Andisols also occur in other areas, including the Rift Valley of Africa, the west coast of Italy, the Hawaiian Islands, the West Indies, Iceland, the Canary Islands, and other islands. In the United States, they are concentrated mostly in the Pacific Northwest, Alaska, and Hawaii.

Profile of an Andisol.

(Back to Key to Soil Orders)



Andisols by suborder in the United States. Note: This map was produced before the introduction of the Gelands suborder. Some areas shown as Cryands in Alaska are now Gelands.



Global distribution of Andisols.

Andisols Suborders

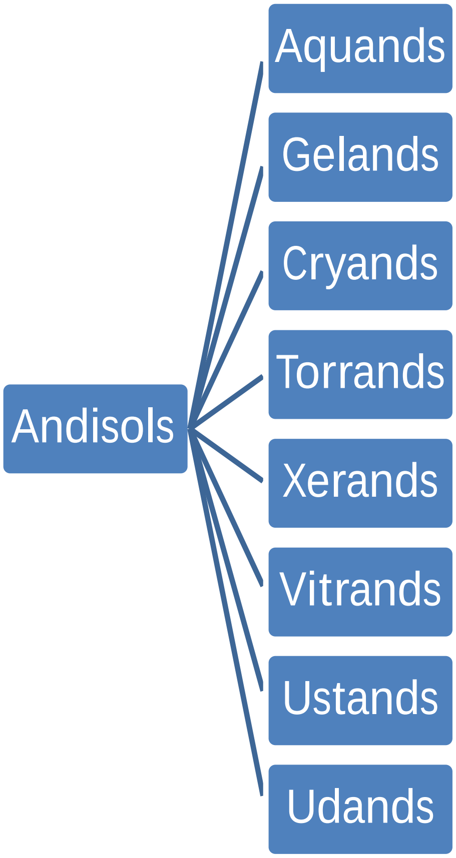
Classification of Andisols

In the definitions of the suborders, emphasis is primarily given to soil moisture and temperature regimes (Aquands, Torrands, Xerands, Ustands, Udands, Gelands, and Cryands). However, in one of the suborders (Vitrands) emphasis is placed on a water-holding capacity that is low relative to that of most other Andisols.

The great group level reflects a combination of important properties, including the presence of a melanic (dark and humus-rich with andic properties) epipedon, a placic (cemented by iron and organic matter) horizon, or other cemented layers; soil moisture or temperature regimes; patterns of soil saturation; and water-holding capacity.

The eight suborders are:

1. Aquands—wet Andisols (aquic conditions in the upper part)
2. Gelands—very cold Andisols that lack permafrost (gelic temperature regime)
3. Cryands—cold Andisols (cryic temperature regime)
4. Torrands—arid Andisols
5. Xerands—moderately dry Andisols (limited moisture that is supplied in winter and Mediterranean-type climate)
6. Vitrands—Andisols with a relatively low water-holding capacity
7. Ustands—moderately dry Andisols (limited moisture)
8. Udands—Andisols of humid regions with well-distributed rainfall


Andisols
Aquands
Gelands
Cryands
Torrands
Xerands
Vitrands
Ustands
Udands

Key to Suborders of Andisols

Andisols that have:

1. **A seasonal high water table within a depth of 50 cm ----------- Aquands**
   A histic epipedon (wet, organic surface layer) and/or redoximorphic features (gray and red mottled color pattern) are evidence of a seasonal high water table. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding color, depth, and location of redoximorphic features in Aquands. Artificially drained sites are included in Aquands.

2. **Very cold average soil temperature ------------------------------------ Gelands**
   These soils have a gelic soil temperature regime.

3. **Cold average soil temperature --- Cryands**
   These soils have a cryic soil temperature regime.

4. **Inadequate soil moisture for crop growth ------------------------- Torrands**
   These soils have an aridic (torric) soil moisture regime.

5. **A Mediterranean-type climate -- Xerands**
   These soils have a xeric soil moisture regime (cool and moist in winter and warm and dry in summer).

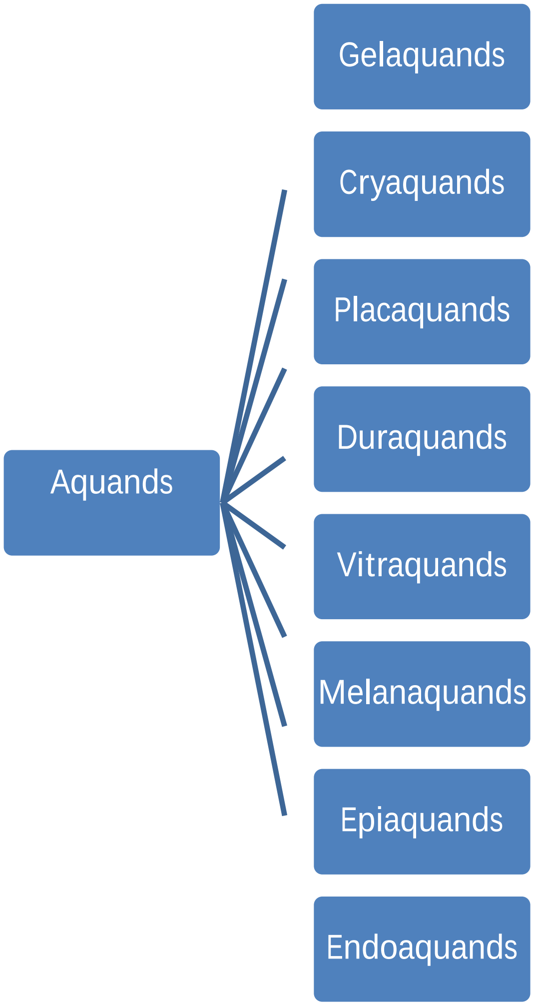
6. **A relatively low water-holding capacity within the upper 60 cm --- Vitrands**
   For Vitrands, water held at 1500 kPa tension is < 15% (by weight) on air-dry samples and < 30% on undried samples. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding location within the profile of this property.

7. **Somewhat limited soil moisture available for crop growth -- Ustands**
   These soils have an ustic soil moisture regime. Moisture is limited, but available, during portions of the growing season.

8. **Seasonally well-distributed precipitation ---------------------------- Udands**
   These soils have a udic soil moisture regime.

Aquands Great Groups

Aquands are the Andisols that are saturated close to the surface by ground water for a long enough period during the year to become devoid of oxygen (aquic conditions). Commonly, these soils have dark-colored, humus-rich surface horizons that meet the requirements for either a histic (wet, organic surface layer), umbric (humus-rich with low base saturation), or mollic (rich in humus and bases) epipedon. They occur in the lower landscape positions and support forest or grass vegetation. Some have been drained and are used for small grain or grass for livestock. Aquands occur in the Pacific Northwest and in other areas that have a volcanic influence.



Key to Great Groups of Aquands (Back to key to suborders)

Aquands that have:

1. **Very cold average soil temperature ------------------------------ Gelaquands**
   These soils have a gelic soil temperature regime.

2. **Cold average soil temperature ------------------------------------- Cryaquands**
   These soils have a cryic soil temperature regime.

3. **A placic (cemented by iron and organic matter) horizon within a depth of 100 cm --- Placaquands**
   The placic horizon must be ≥ 50% of the pedon. Begin measuring below any organic surface layer (O), unless the O horizon has andic soil properties.

4. **A cemented layer within a depth of 100 cm ------------------- Duraquands**
   The cemented layer must be ≥ 75% of the pedon. Begin measuring below any organic surface layer (O), unless the O horizon has andic soil properties.

5. **A relatively low water-holding capacity within the upper 60 cm -- Vitraquands**
   For Vitraquands, water held at 1500 kPa tension is < 15% (by weight) on air-dry samples and < 30% on undried samples. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding location within the profile of this property.

6. **A melanic (dark and humus-rich with andic properties) epipedon -- Melanaquands**

7. **Episaturation (perched water table) ------------------------------ Epiaquands**

8. **Endosaturation (saturated throughout the profile) ------- Endoaquands**

Descriptions of Great Groups of Aquands

Gelaquands—These are the more or less poorly drained Andisols of very cold regions. They are not extensive. These soils have a gelic temperature regime but lack permafrost within the soil profile. They tend to be in landscape positions that are subject to wide variations in summer high temperatures and winter low temperatures, which result in mean annual soil temperatures of 0 degrees C or less, but without permafrost. (Back to Aquands key)

Cryaquands—These are the more or less poorly drained Andisols of cold regions. They are not extensive. These soils are mostly in the western part of North America and the northeastern part of Asia above 49 degrees north latitude and in mountains south of that latitude. Most of these soils formed under grassy meadow or coniferous forest vegetation. Characteristically, Cryaquands have a thin O horizon, a mollic (rich in humus and bases) or umbric (humus-rich with low base saturation) epipedon, and a cambic (minimal soil development) subsoil horizon with many redoximorphic concentrations (reddish mottled color pattern). In the United States, the Cryaquands generally developed in late-Pleistocene or Holocene deposits. (Back to Aquands key)

Placaquands—These are the more or less poorly drained Andisols that have, in half or more of each pedon, a placic (cemented by iron and organic matter) horizon within 100 cm of the mineral soil surface or of the upper boundary of an organic layer that has andic soil properties, whichever is shallower. Most of these soils formed under coniferous forest vegetation. Characteristically, Placaquands have a thin O horizon and an umbric (humus-rich with low base saturation) or histic (wet, organic surface layer) epipedon above the placic horizon. They are rare in the United States. (Back to Aquands key)

Duraquands—These are the more or less poorly drained Andisols that have, in 75% or more of each pedon, a cemented horizon (duripan or other cemented layer) that has its upper boundary within 100 cm of the mineral soil surface or of the top of an organic layer with andic soil properties, whichever is shallower. Duraquands are rare in the United States but known to occur in the Pacific Northwest. (Back to Aquands key)

Vitraquands—These are the more or less poorly drained Andisols with relatively coarse textures. Most of these soils have no slowly permeable layer that causes unsaturated layers to underlie saturated layers within a depth of 200 cm. Many of these soils formed under grassy or brushy meadow vegetation, but some formed under coniferous forest vegetation. Characteristically, Vitraquands have a thin O horizon, a mollic (rich in humus and bases) or umbric (humus-rich with low base saturation) epipedon, and a cambic (minimal soil development) subsoil horizon with many redoximorphic concentrations (reddish mottled color pattern). In the United States, most Vitraquands developed in Holocene deposits. (Back to Aquands key)

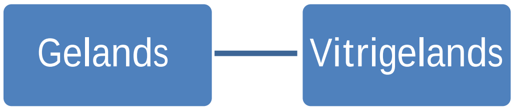
Melanaquands—These are the more or less poorly drained Andisols with a melanic (dark and humus-rich with andic properties) epipedon. Most of these soils formed under forest vegetation. Characteristically, Melanaquands have a thin O horizon, a thick melanic (dark and humus-rich with andic properties) epipedon, and a cambic (minimal soil development) subsoil horizon with many redoximorphic concentrations (reddish mottled color pattern). (Back to Aquands key)

Epiaquands—These are the more or less poorly drained Andisols with a slowly permeable layer that results in saturated layers overlying unsaturated layers within a depth of 200 cm. Most of these soils formed under grassy meadow vegetation, but some formed under coniferous forest vegetation. Characteristically, Epiaquands have a thin O horizon, a mollic (rich in humus and bases) or umbric (humus-rich with low base saturation) epipedon, and a cambic (minimal soil development) subsoil horizon with many redoximorphic concentrations (reddish mottled color pattern). In the United States, Epiaquands generally developed in late-Pleistocene or Holocene deposits. (Back to Aquands key)

Endoaquands—These are the more or less poorly drained Andisols that are saturated in all layers to a depth of 200 cm. Most of these soils formed under grassy meadow vegetation, but some formed under coniferous forest vegetation. Characteristically, Endoaquands have a thin O horizon, a mollic (rich in humus and bases) or umbric (humus-rich with low base saturation) epipedon, and a cambic (minimal soil development) subsoil horizon with many redoximorphic concentrations (reddish mottled color pattern). In the United States, Endoaquands generally developed in late-Pleistocene or Holocene deposits. (Back to Aquands key)

Gelands Great Groups

Gelands are the Andisols of very cold regions. They have a gelic temperature regime but lack permafrost within the soil profile. These soils tend to be in landscape positions that are subject to wide variations in summer high temperatures and winter low temperatures, which result in mean annual soil temperatures of 0 degrees C or less, but without permafrost.



Key to Great Groups of Gelands (Back to key to suborders)

Gelands that have:

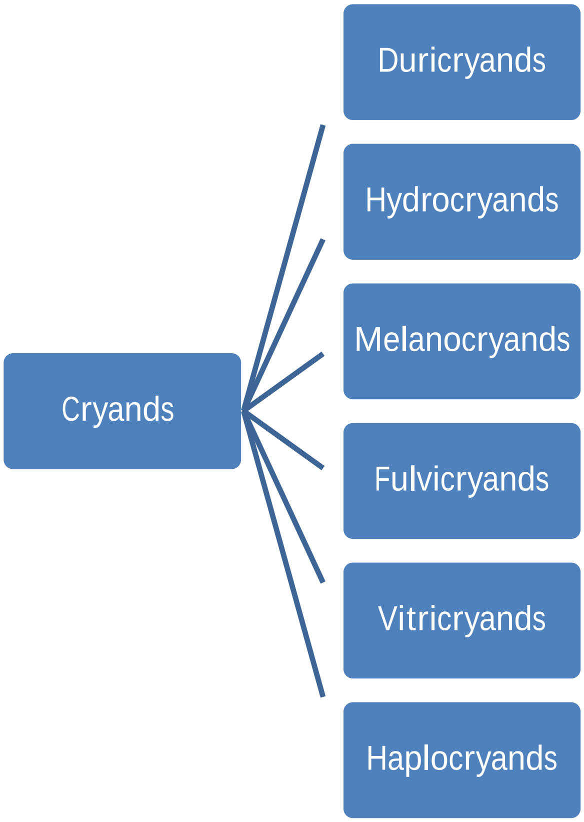
1. **A relatively low water-holding capacity ------------------------- Vitrigelands**
   Currently, this is the only great group of Gelands, so all Gelands currently are classified as Vitrigelands. Specific criteria are not developed.

Descriptions of the Great Group of Gelands

Vitrigelands—Currently, this is the only great group of Gelands recognized. These soils tend to be coarse in texture and have a relatively low water-holding capacity. (Back to Gelands key)

Cryands Great Groups

Cryands are the more or less well drained Andisols of cold regions. These soils are moderately extensive. They formed in the western part of North America and the northeastern part of Asia above 49 degrees north latitude and in mountains south of that latitude. Most of the soils formed under coniferous forest vegetation. Characteristically, Cryands have a thin O horizon and a cambic (minimal soil development) subsoil horizon. The epipedon is commonly the simple ochric (typically thin and/or light-colored) or melanic (dark and humus-rich with andic properties). In the United States, Cryands generally developed in late-Pleistocene or Holocene deposits.



Key to Great Groups of Cryands (Back to key to suborders)

Cryands that have:

1. **A cemented layer within a depth of 100 cm ------------------ Duricryands**
   The cemented layer must be ≥ 75% of the pedon. Begin measuring below any organic surface layer (O), unless the O horizon has andic soil properties.

2. **A very high water-holding capacity within the upper 100 cm --- Hydrocryands**
   For Hydrocryands, water held at 1500 kPa tension is ≥ 100% (by weight) on undried samples. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding location within the profile of this property.

3. **A melanic (dark and humus-rich with andic properties) epipedon --- Melanocryands**

4. **A melanic-like epipedon (but lighter in color) -------------- Fulvicryands**

5. **A relatively low water-holding capacity within the upper 60 cm --- Vitricryands**
   For Vitraquands, water held at 1500 kPa tension is < 15% (by weight) on air-dry samples and < 30% on undried samples. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding location within the profile of this property.

6. **A cambic (minimal soil development) horizon ------------- Haplocryands**

Descriptions of Great Groups of Cryands

Duricryands—These are Cryands that have, in 75% or more of each pedon, a cemented horizon (duripan or other cemented layer) that has its upper boundary within 100 cm of either the mineral soil surface or the top of an organic layer with andic soil properties, whichever is shallower. Characteristically, Duricryands have a thin O horizon and a cambic (minimal soil development) subsoil horizon above the cemented horizon. In the United States, Duricryands generally developed in late-Pleistocene or Holocene deposits. Most formed under coniferous forest vegetation. (Back to Cryands key)

Hydrocryands—These soils have the capacity to absorb and store large amounts of water. On undried samples, they have 1500 kPa (wilting point) water retention of 100% (by weight) or more throughout 60% or more of the upper part of the pedon. Hydrocryands have not been recognized in the United States. Most formed under coniferous forest vegetation. (Back to Cryands key)

Melanocryands—These soils have a melanic (dark and humus-rich with andic properties) epipedon. Most have a cambic (minimal soil development) subsoil horizon. Melanocryands have not been recognized in the United States. (Back to Cryands key)

Fulvicryands—These soils have a surface layer that meets the depth, thickness, and organic-carbon requirements for a melanic epipedon but is lighter in color. Characteristically, Fulvicryands have a thin O horizon, an umbric (humus-rich with low base saturation) epipedon, and a cambic (minimal soil development) horizon. The Fulvicryands in the United States generally developed in late-Pleistocene or Holocene deposits. Most formed under coniferous forest vegetation. (Back to Cryands key)

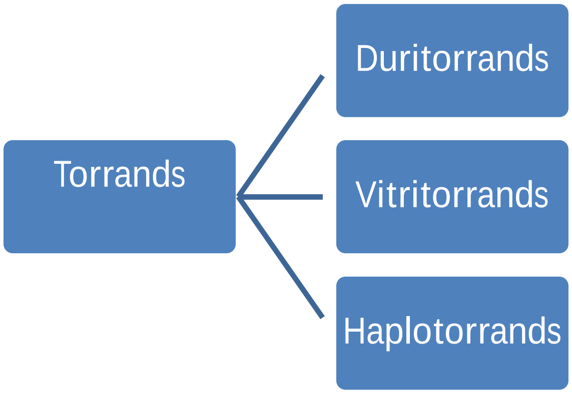
Vitricryands—These soils have relatively coarse textures and a low water-holding capacity. They have 1500 kPa water retention of less than 15% (by weight) on air-dried samples and less than 30% on undried samples throughout 60% or more of the upper 60 cm of the andic materials. Characteristically, Vitricryands have a thin O horizon, an ochric (typically thin and/or light-colored), mollic (rich in humus and bases) or umbric (humus-rich with low base saturation) epipedon, and a cambic (minimal soil development) subsoil horizon. The Vitricryands in the United States generally developed in Holocene deposits. Most formed under coniferous forest vegetation. (Back to Cryands key)

Haplocryands—Characteristically, Haplocryands have a thin O horizon, an umbric (humus-rich with low base saturation) epipedon, and a cambic (minimal soil development) subsoil horizon. The Haplocryands in the United

States generally developed in late-Pleistocene or Holocene deposits. Most formed under coniferous forest vegetation. (Back to Cryands key)

Torrands Great Groups

Torrands are the more or less well drained Andisols of dry regions. These soils are not extensive. Some formed in the western part of North America, and some are known to occur in Hawaii and other Pacific Islands. Most of the soils formed under grassy or shrub vegetation. Characteristically, Torrands have an ochric (typically thin and/or light-colored) or mollic (rich in humus and bases) epipedon and a cambic (minimal soil development) subsoil horizon. Some have a duripan (layer cemented by silica) or a petrocalcic (cemented by calcium carbonate) horizon in the subsoil. In the United States, the Torrands generally developed in late-Pleistocene or Holocene deposits.



Key to Great Groups of Torrands (Back to key to suborders)

Torrands that have:

1. **A cemented horizon within a depth of 100 cm --------------- Duritorrands**
   The cemented layer must be ≥ 75% of the pedon. Begin measuring below any organic surface layer (O), unless the O horizon has andic soil properties.

2. **A relatively low water-holding capacity within the upper 60 cm --- Vitritorrands**
   For Vitritorrands, water held at 1500 kPa tension is < 15% (by weight) on air-dry samples. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding location within the profile of this property.

3. **A cambic (minimal soil development) horizon ------------ Haplotorrands**

Descriptions of Great Groups of Torrands

Duritorrands—These soils have, in 75% or more of each pedon, a cemented horizon (duripan or other cemented layer) that has its upper boundary within 100 cm of either the mineral soil surface or the top of an organic layer with andic soil properties, whichever is shallower. Characteristically, these soils have an ochric (typically thin and/or light-colored) or mollic (rich in humus and bases) epipedon and a cambic (minimal soil development) subsoil horizon above the cemented horizon. The Duritorrands in the United States generally developed in late-Pleistocene deposits. Most formed under grass or shrub vegetation, and some have widely spaced trees. (Back to Torrands key)

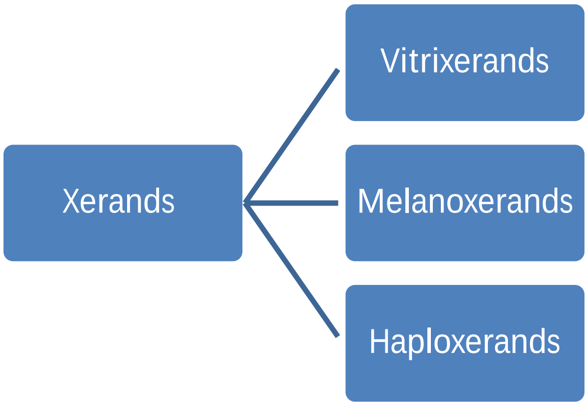
Vitritorrands—These soils have relatively coarse texture and a low water-holding capacity. They have, on air-dried samples, a 1500 kPa (wilting point) water retention of less than 15% (by weight) throughout 60% or more of the thickness within 60 cm of the mineral soil surface or the top of an organic layer with andic soil properties, whichever is shallower. Characteristically, Vitritorrands have an ochric (typically thin and/or light-colored) or mollic (rich in humus and bases) epipedon and a cambic (minimal soil development) subsoil horizon. The Vitritorrands in the United States generally developed in Holocene deposits. Most formed under grass or shrub vegetation, and some have widely spaced trees. (Back to Torrands key)

Haplotorrands—Characteristically, Haplotorrands have an ochric (typically thin and/or light-colored) or mollic (rich in humus and bases) epipedon and a cambic (minimal soil development) subsoil horizon. The Haplotorrands in the United States generally developed in late-Pleistocene deposits. Most formed under grass or shrub vegetation, and some have widely spaced trees. (Back to Torrands key)

Xerands Great Groups

Xerands are in regions that have a Mediterranean-type climate. As their name implies, these soils have a xeric moisture regime. They are dry for extended periods in summer. In winter, in some if not most years, moisture moves through the soils to the deeper layers. Most of the Xerands in the United States are in Oregon, Washington, Idaho, and California, formed under coniferous forest vegetation, and have cool or moderate average soil temperatures. Some formed under grass or shrub vegetation.

Characteristically, Xerands have an ochric (typically thin and/or light-colored) or mollic (rich in humus and bases) epipedon and a cambic (minimal soil development) subsoil horizon. Some have a melanic (dark and humus-rich with andic properties) epipedon. Most of the Xerands in the United States developed in late-Pleistocene or Holocene deposits.



Profile of a Xerand in Turkey. This soil is specifically a Vitrixerand and formed in volcanic ash deposits.

Back to Xerands

Key to Great Groups of Xerands (Back to key to suborders)

Xerands that have:

1. **A relatively low water-holding capacity within the upper 60 cm -- Vitrixerands**
   For Vitrixerands, water held at 1500 kPa tension is < 15% (by weight) on air-dry samples and < 30% on undried samples. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding location within the profile of this property.

2. **A melanic (dark and humus-rich with andic properties) epipedon --- Melanoxerands**

3. **A cambic (minimal soil development) horizon ------------- Haploxerands**

Descriptions of Great Groups of Xerands

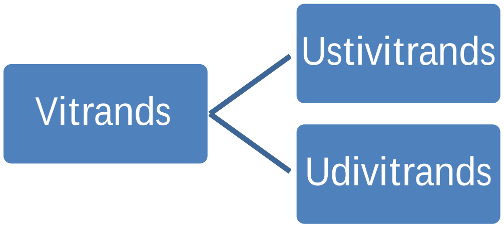
Vitrixerands—These soils have relatively coarse textures and a low water-holding capacity. They are relatively young soils that, in many areas, occur near volcanoes. These soils are moderately extensive in the United States and occur mostly in Oregon, Washington, and Idaho. They formed mainly under coniferous forest vegetation. Commonly, Vitrixerands have an ochric (typically thin and/or light-colored) or mollic (rich in humus and bases) epipedon and a cambic (minimal soil development) subsoil horizon. Most of the Vitrixerands in the United States developed in Holocene or late-Pleistocene deposits. (Back to Xerands key)

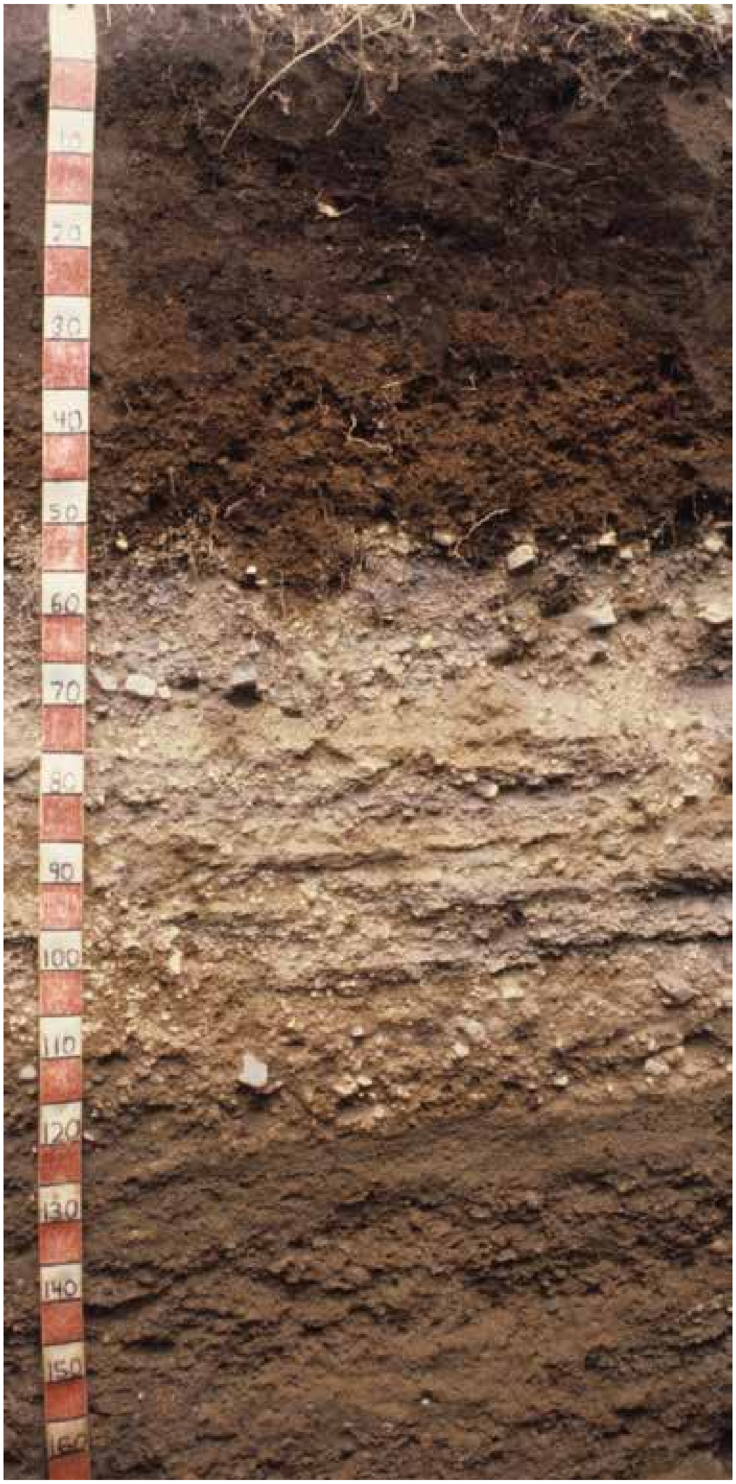
Melanoxerands—These soils have a melanic (dark and humus-rich with andic properties) epipedon and commonly have a cambic (minimal soil development) subsoil horizon. Most of the Melanoxerands in the United States developed in late-Pleistocene or Holocene deposits. Most formed under forest or savanna vegetation. (Back to Xerands key)

Haploxerands—These soils have a thin O horizon, an ochric (typically thin and/or light-colored) or mollic (rich in humus and bases) epipedon, and a cambic (minimal soil development) subsoil horizon. The Haploxerands in the United States generally developed in late-Pleistocene or Holocene deposits. Most formed under coniferous forest vegetation, but some formed under grass or shrub vegetation. (Back to Xerands key)

Vitrands Great Groups

Vitrands are the more or less well drained, coarse textured Andisols with a relatively low water-holding capacity. These are relatively young soils that occur mostly near volcanoes. Most of the Vitrands in the United States are in Oregon, Washington, and Idaho and formed mainly under coniferous forest vegetation. Characteristically, Vitrands have an ochric (typically thin and/or light-colored), mollic (rich in humus and bases), umbric (humus-rich with low base saturation), or melanic (dark and humus-rich with andic properties) epipedon and a cambic (minimal soil development) subsoil horizon. Most of the Vitrands in the United States developed in Holocene deposits.





Profile of a Vitrand (specifically an Ustivitrand) in the Philippines. This soil has an umbric epipedon. Scale is in cm.

(Back to Vitrands)

Key to Great Groups of Vitrands (Back to key to suborders)

Vitrands that have:

1. **Somewhat limited soil moisture available for plant growth -- Ustivitrands**
   These soils have an ustic soil moisture regime. Moisture is limited, but available, during portions of the growing season.

2. **Seasonally well-distributed precipitation ---------------------- Udivitrands**
   These soils have an udic soil moisture regime.

Descriptions of Great Groups of Vitrands

Ustivitrands—These soils have an ustic moisture regime. Moisture is limited, but available, during portions of the growing season. Characteristically, Ustivitrands have an ochric (typically thin and/or light-colored) epipedon and a cambic (minimal soil development) subsoil horizon. Ustivitrands are rare in the United States. (Back to Vitrands key)

Udivitrands—These soils have a udic moisture regime. Precipitation is distributed throughout the year. Characteristically, these soils have an ochric (typically thin and/or light-colored) epipedon and a cambic (minimal soil development) subsoil horizon. Some have an argillic (clay accumulation) subsoil horizon. Most of the Udivitrands in the United States developed in Holocene deposits under coniferous forest vegetation. (Back to Vitrands key)

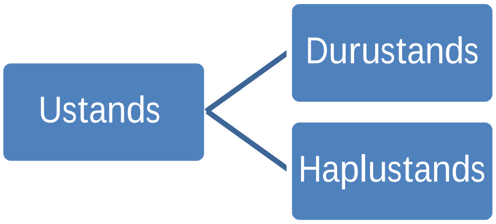
Profile of a Udivitrand in the Pacific Northwest region of the United States. It has a dark ochric epipedon about 10 cm thick underlain by a slightly reddened cambic horizon that extends to a depth of about 85 cm. The soil formed in a mixture of washed-in deposits of volcanic ash and loamy sediments. It has a significant content of small particles of volcanic glass (visible under magnification). Scale is in cm.

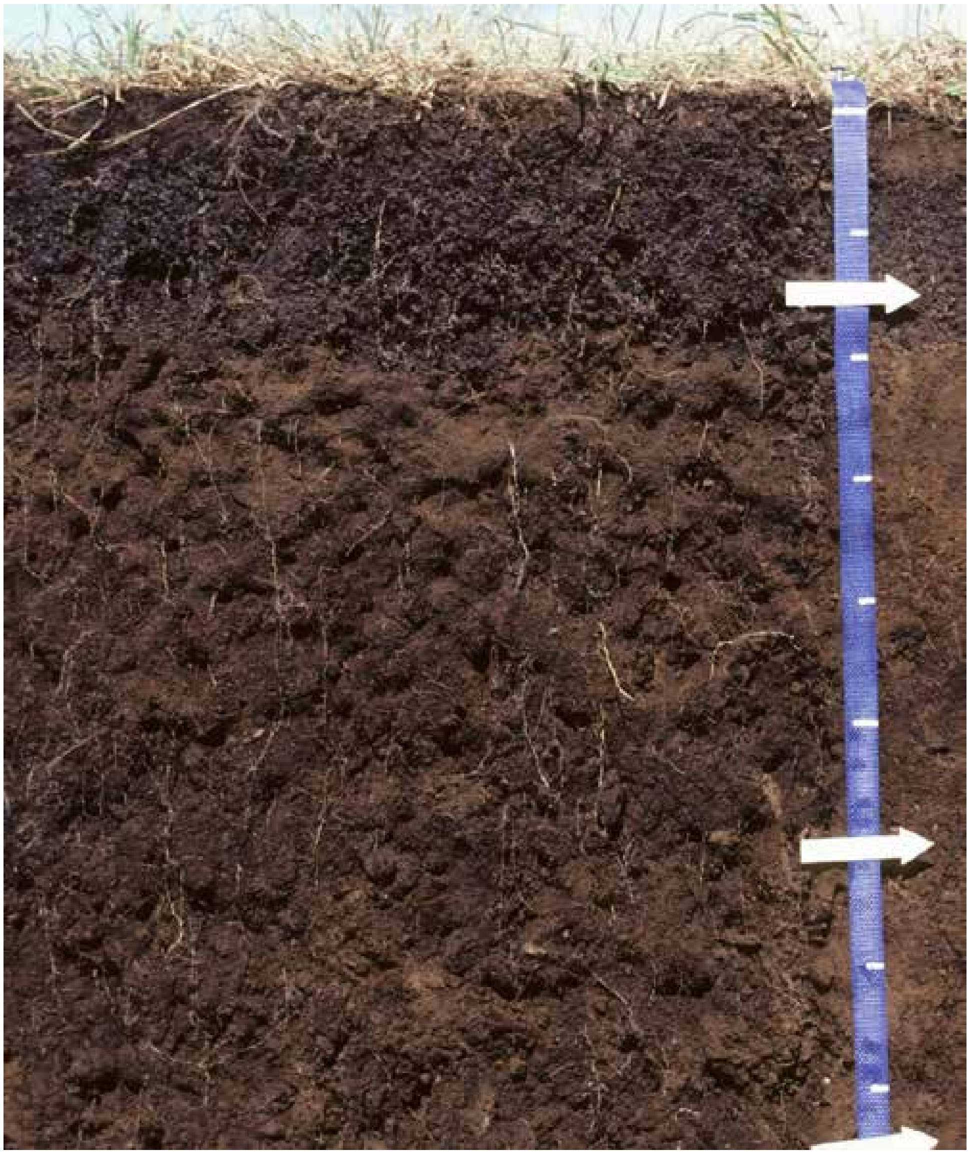
Return to Udivitrands

Ustands Great Groups

Ustands are the more or less well drained Andisols of subhumid to semiarid regions. These soils are of relatively small extent. They are mostly in Mexico, the western part of the United States, the Pacific Islands, and the eastern part of Africa. Most Ustands in the United States are in Hawaii, Arizona, and New Mexico. Most formed under grass, shrub, or forest vegetation.

Characteristically, Ustands have an ochric (typically thin and/or light-colored) or mollic (rich in humus and bases) epipedon and a cambic (minimal soil development) subsoil horizon. Some have a duripan. The Ustands in the United States generally developed in late-Pleistocene or Holocene deposits.





Profile of an Ustand (specifically a Haplustand) in Chile. Scale is in decimeters. Arrows indicate horizon boundary locations.

Back to Ustands

Key to Great Groups of Ustands (Back to key to suborders)

Ustands that have:

1. **A cemented horizon within a depth of 100 cm ---------------- Durustands**
   The cemented layer must be ≥ 75% of the pedon. Begin measuring below any organic surface layer (O), unless the O horizon has andic soil properties.

2. **A cambic (minimal soil development) horizon --------------- Haplustands**

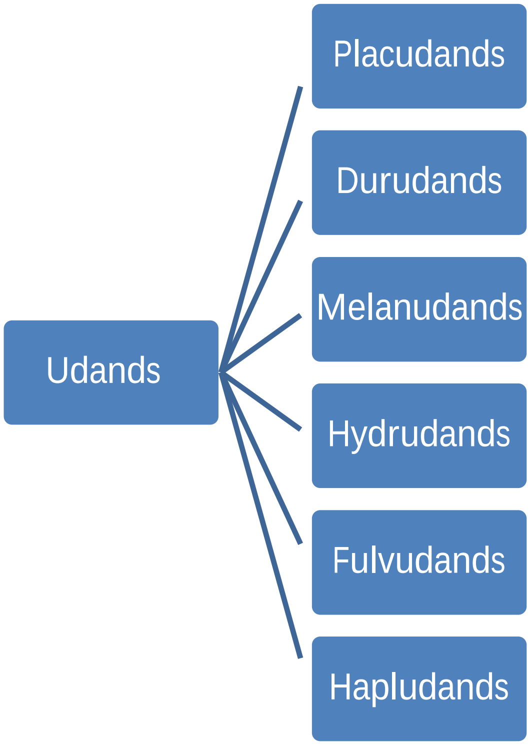
Descriptions of Great Groups of Ustands

Durustands—These soils have, in 75% or more of each pedon, a cemented horizon (duripan or other cemented layer) with its upper boundary within 100 cm of either the mineral soil surface or of the top of an organic layer with andic soil properties, whichever is shallower. Characteristically, Durustands have an ochric (typically thin and/or light-colored) epipedon and a cambic (minimal soil development) subsoil horizon above the cemented horizon. Some have a mollic (rich in humus and bases) epipedon. The Durustands in the United States generally developed in late-Pleistocene or Holocene deposits. Most formed under coniferous/grass or shrub vegetation. (Back to Ustands key)

Haplustands—These soils have an ochric (typically thin and/or light-colored) epipedon and a cambic (minimal soil development) subsoil horizon. Some have a mollic (rich in humus and bases) epipedon. The Haplustands in the United States generally developed in late-Pleistocene or Holocene deposits. Most formed under coniferous vegetation or grass or shrub vegetation. (Back to Ustands key)

Udands Great Groups

Udands are the more or less well drained Andisols of humid climates. These soils are moderately extensive. They are mostly on the Pacific Rim, mainly in the western part of North America and in Japan, New Zealand, the Philippines, and Indonesia. Most of the Udands in the United States are in Washington and Oregon, but some are in Hawaii. Most Udands formed under forest vegetation. Characteristically, Udands have an ochric (typically thin and/or light-colored) or umbric (humus-rich with low base saturation) epipedon and a cambic (minimal soil development) subsoil horizon. Some have a melanic (dark and humus-rich with andic properties) epipedon, and some have a duripan (layer cemented by silica) or placic (cemented by iron and organic matter) horizon. Most of the Udands in the United States developed in late-Pleistocene or Holocene deposits.



Profile of a Udand (specifically a Hapludand) in Japan. This soil formed in several ash deposits and contains a series of paleosols. Scale is in decimeters.

(Back to Udands)

Key to Great Groups of Udands (Back to key to suborders)

Udands that have:

1. **A placic (cemented by iron and organic matter) horizon within a depth of 100 cm -- Placudands**
   The placic horizon must be ≥ 50% of the pedon. Begin measuring below any organic surface layer (O), unless the O horizon has andic soil properties.

2. **A cemented horizon within a depth of 100 cm ----------------- Durudands**
   The cemented layer must be ≥ 75% of the pedon. Begin measuring below any organic surface layer (O), unless the O horizon has andic soil properties.

3. **A melanic (dark and humus-rich with andic properties) epipedon --- Melanudands**

4. **A very high water-holding capacity within the upper 100 cm -- Hydrudands**
   For Hydrudands, water held at 1500 kPa tension is ≥ 100% (by weight) on undried samples. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding location within the profile of this property.

5. **A melanic-like epipedon (but lighter in color) ----------------- Fulvudands**

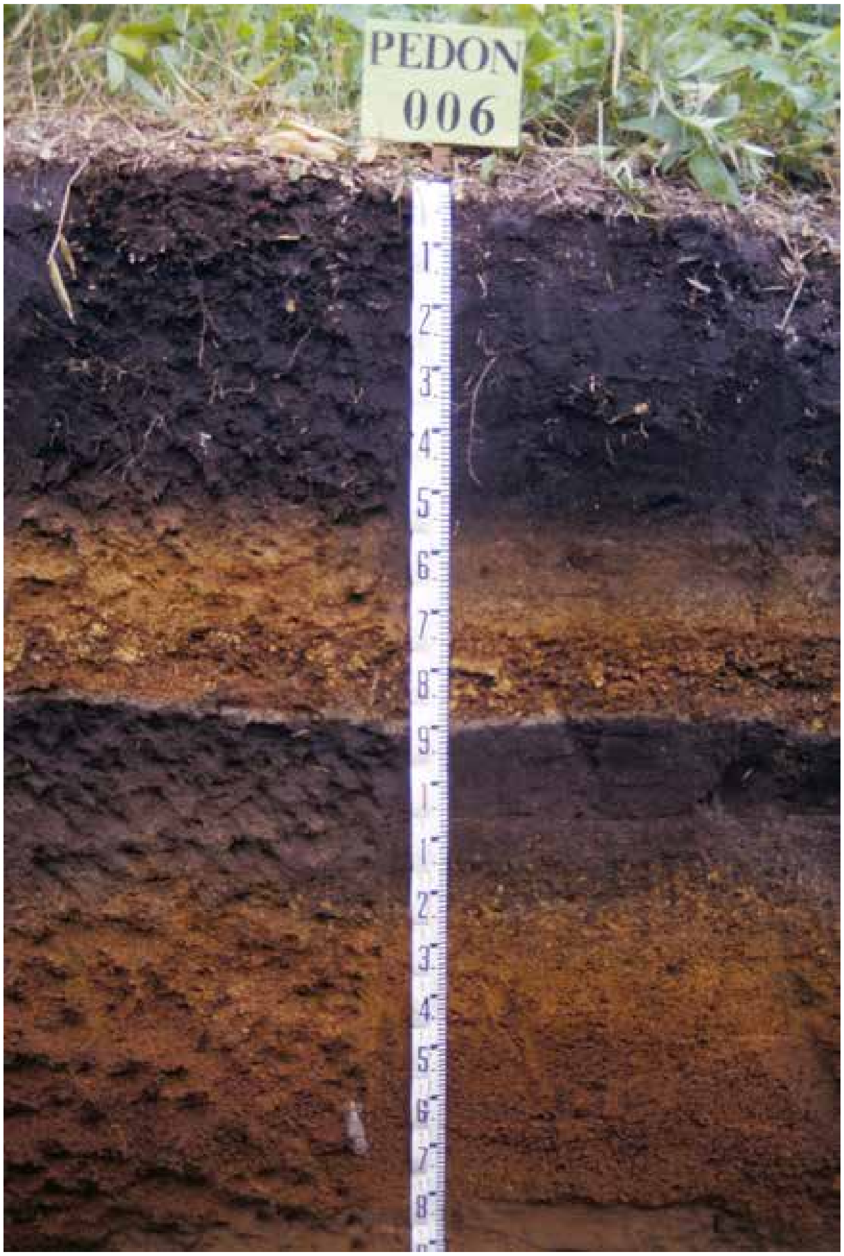
6. **A cambic (minimal soil development) horizon ---------------- Hapludands**

Descriptions of Great Groups of Udands

Placudands—These soils have, in half or more of each pedon, a placic (cemented by iron and organic matter) horizon within 100 cm of either the mineral soil surface or the top of an organic layer with andic soil properties, whichever is shallower. Characteristically, Placudands have a thin O horizon and an ochric (typically thin and/or light-colored) or umbric (humus-rich with low base saturation) epipedon above the placic horizon. Placudands are rare in the United States. Most formed under forest vegetation. (Back to Udands key)

Durudands—These soils have, in 75% or more of each pedon, a cemented horizon that has its upper boundary within 100 cm of the mineral soil surface or of the upper boundary of an organic layer that has andic soil properties, whichever is shallower. Characteristically, Durudands have a thin O horizon, an ochric (typically thin and/or light-colored) or umbric (humus-rich with low base saturation) epipedon, a cambic (minimal soil development) subsoil horizon, and a cemented horizon (duripan or other cemented layer). The Durudands in the United States generally developed in late-Pleistocene deposits. Most formed under coniferous forest vegetation. (Back to Udands key)

Melanudands—These soils have a melanic (dark and humus-rich with andic properties) epipedon and a cambic (minimal soil development) subsoil horizon. The Melanudands in the United States generally developed in late-Pleistocene deposits. Most formed under forest or savanna vegetation. (Back to Udands key)



Profile of a Melanudand in Japan. The soil formed in successive layers of volcanic ash and debris. It has a thick, dark, humus-rich melanic epipedon about 55 cm thick. A cambic horizon extends from depths of 55 to 90 cm. An older surface layer, now covered by more recent deposits, can be seen between depths of 90 and 120 cm. The right side of the profile has been smoothed; the left side retains the natural soil structure. Scale is cm.

Return to Melanudands

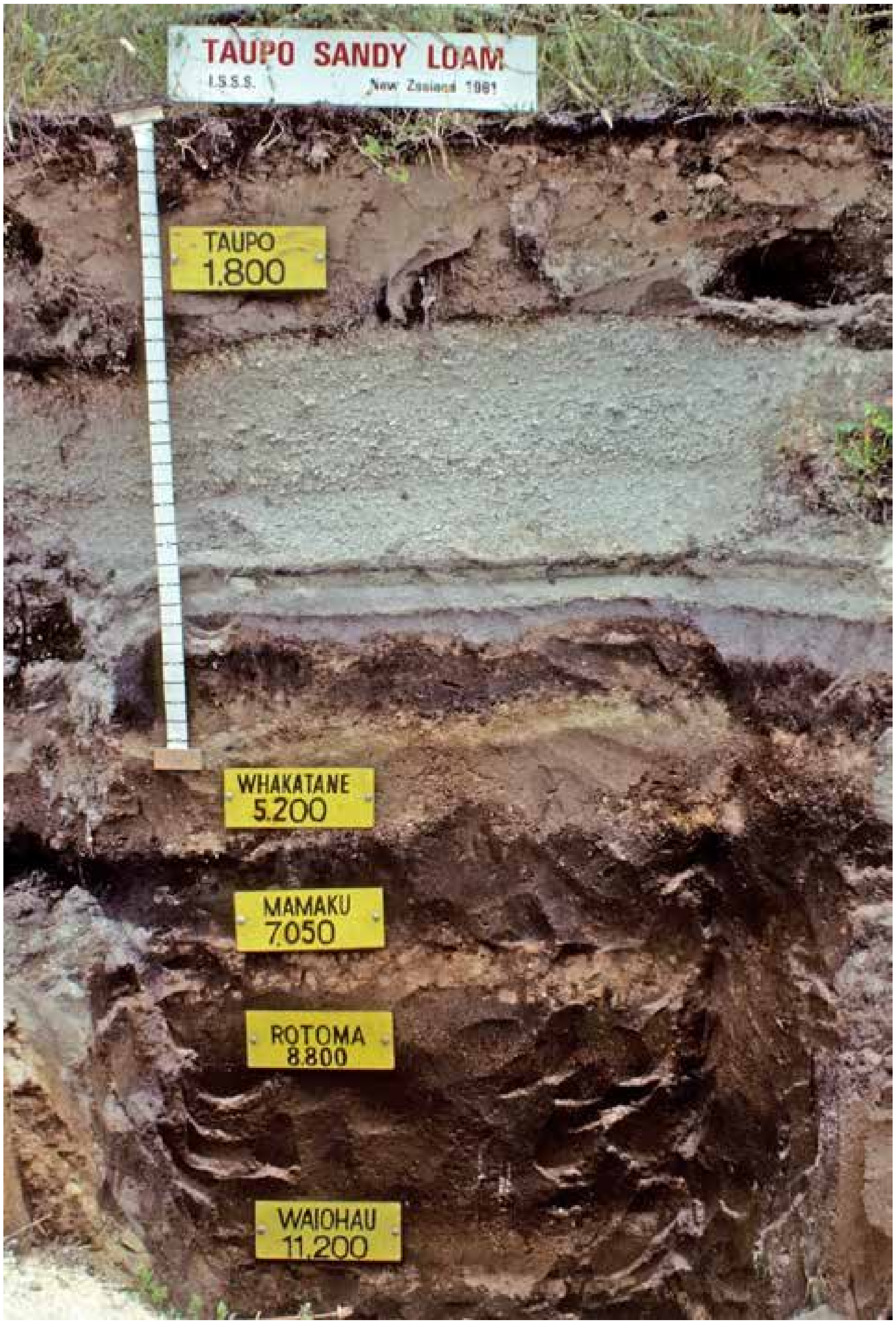
Hydrudands—These soils have the capacity to absorb and store large amounts of water. On undried samples, they have a 1500 kPa (wilting point) water retention of 100% or more, by weighted average, throughout the major part of the andic materials. Commonly, Hydrudands have a thin O horizon, an ochric (typically thin and/or light-colored) or umbric (humus-rich with low base saturation) epipedon, and a cambic (minimal soil development) subsoil horizon. Most of the Hydrudands in the United States developed in late-Pleistocene deposits under forest vegetation. (Back to Udands key)

Fulvudands—These soils have a surface layer that meets the depth, thickness, and organic-carbon requirements for a melanic epipedon but is lighter in color. Characteristically, Fulvudands have a thin O horizon, an umbric (humus-rich with low base saturation) epipedon, and a cambic (minimal soil development) subsoil horizon. The Fulvudands in the United States generally developed in late-Pleistocene deposits. Most formed under coniferous forest vegetation. (Back to Udands key)

Profile of a Fulvudand in Washington State. This soil formed in material weathered from basalt bedrock with an admixture of volcanic ash in roughly the upper 50 cm. This profile has an umbric epipedon extending from the surface to a depth of about 25 cm. Below this epipedon is a cambic horizon that extends to about 120 cm. Scale is in cm.

Return to Fulvudands

Hapludands—Commonly, Hapludands have a thin O horizon, an ochric (typically thin and/or light-colored) or umbric (humus-rich with low base saturation) epipedon, and a cambic (minimal soil development) subsoil horizon. Most of the Hapludands in the United States developed in late-Pleistocene or Holocene deposits. Most formed under coniferous forest vegetation. (Back to Udands key)



Profile of a Hapludand in New Zealand. The soil formed in a series of volcanic ash deposits spanning a period of about 11,200 years. The labels identify the ages (years before present) of volcanic eruptions. The darker horizons represent surface layers that formed during relatively stable periods between eruptions. Scale is in 5-cm increments.

Return to Hapludands

Aridisols Order

Aridisols are the dry soils of deserts.

General Characteristics

Aridisols have very limited soil moisture available for the growth of plants. Typically, these soils have a simple ochric (typically thin and/or light-colored) epipedon for a surface layer. In some places, this surface layer has many small, rounded viscular pores that formed as a result of the trapping of air during periodic intense rains. The surface layer of some Aridisols commonly is blanketed by a thin physical or biological crust.

Aridisols have at least one of several possible forms of subsoil horizons that are, for the most part, indicative of a low leaching environment, where various salts and other water-soluble minerals accumulate in the subsoil. These forms commonly include calcic (calcium carbonate accumulation), gypsic (gypsum accumulation), and salic (high salts) horizons as well as the highly developed and cemented petrocalcic (cemented by calcium carbonate) horizon, petrogypsic (cemented by gypsum) horizon, and duripan (layer cemented by silica). In addition, some Aridisols have a cambic (minimal soil development), argillic (clay accumulation), or natric (high levels of illuvial clay and sodium) subsoil horizon.

Environment and Processes

As the name suggests, Aridisols are found in desert environments where evaporation greatly exceeds precipitation and therefore water is not available to mesophytic plants for long periods of time. Since the limited rainfall only percolates to shallow depths before it evaporates or is absorbed by plants and other soil organisms, the water-soluble salts that are carried downward by the water tend to accumulate in the soil to the depth of wetting. In areas with higher amounts of rainfall, these salts would be removed fairly easily from the profile by leaching. Due to the imbalance between evapotranspiration and precipitation, they accumulate in Aridisols.

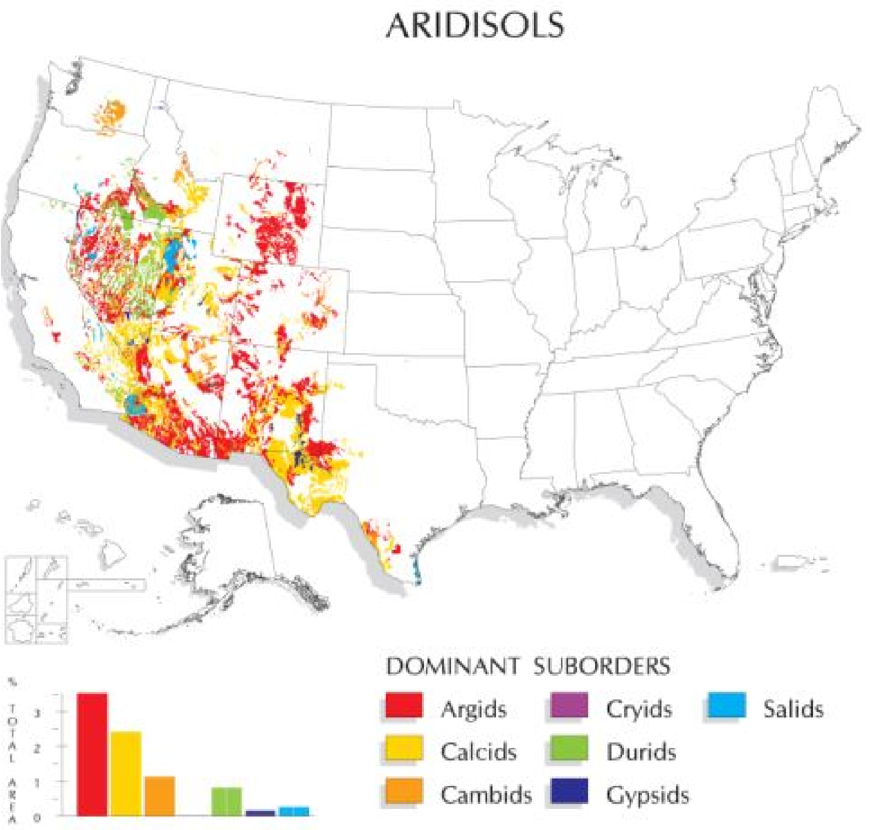
A few very salty Aridisols have a high water table. In these Aridisols, salts that are carried by evaporating water tend to move upward toward the surface, where they accumulate. These “wet Aridisols” are characteristic of some playas in the western United States as well as the sabkhas of North Africa and the Middle East. Due to the salt-induced high osmotic potential, only salt-tolerant halophytes can obtain this water. The water is held at tensions too high for other plants. These effectively “dry” soils are also included in the Aridisols.

Location

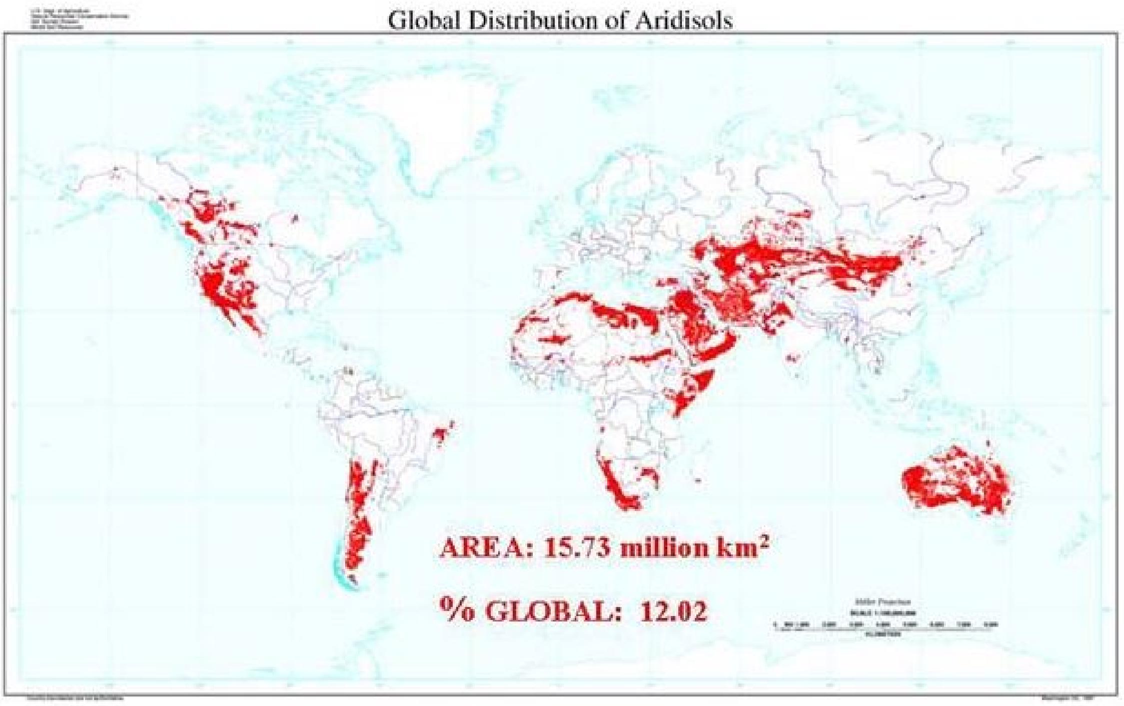
Aridisols are found throughout the world in desert environments. Globally, they occupy about 12% of the ice-free land area. They occur in North America, South America, Africa, the Middle East, Asia, and Australia. These environments include both hot and cold deserts and cover a wide range in both latitude and elevation. In the United States, Aridisols are common in the western deserts.

Profile of an Aridisol (specifically a Haplocalcid) in the United Arab Emirates. White concentrations are calcium carbonate masses. Scale is in cm. (Photo courtesy of Dr. Craig Ditzler)

(Back to Key to Soil Orders)



Aridisols by suborder in the United States.



Global distribution of Aridisols.

Aridisols Suborders

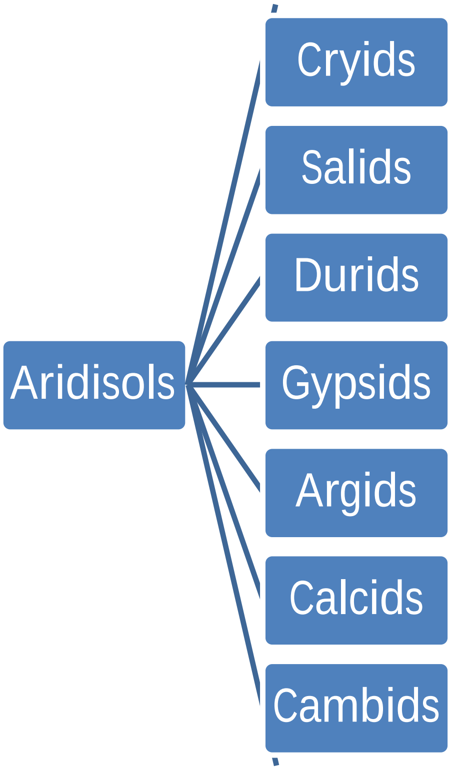
Classification of Aridisols

In the definition of the suborders, emphasis is given to the redistribution of soluble materials and their accumulation in the subsoil or surface layer. Four of the seven suborders are defined on the basis of the composition and accumulation of the soluble fraction (Salids, Durids, Gypsids, and Calcids). Weathering and clay translocation also take place in Aridisols. Two suborders reflect these processes (Argids and Cambids). One suborder reflects very cold temperature (Cryids).

The great group level reflects the degree of expression of the horizons of accumulation and/or the results of other processes that are considered subordinate to the particular suborder. The defining element is the degree of expression of the diagnostic horizon.

The seven suborders are:

1. Cryids—Aridisols in cold areas
2. Salids—Aridisols with an accumulation of salts more soluble than gypsum
3. Durids—Aridisols with an accumulation of and cementation by silica
4. Gypsids—Aridisols with an accumulation of gypsum
5. Argids—Aridisols with an accumulation of clay
6. Calcids—Aridisols with an accumulation of carbonates
7. Cambids—Aridisols with translocation and/or transformation of material



Key to the Suborders of Aridisols

Aridisols that have:

1. **Cold average soil temperature -- Cryids**
   These soils have a cryic soil temperature regime.

2. **A salic (high content of salts) horizon within a depth of 100 cm -- Salids**

3. **A duripan (layer cemented by silica) within a depth of 100 cm -- Durids**

4. **A gypsic (gypsum accumulation) or petrogypsic (cemented by gypsum) horizon within a depth of 100 cm -------------------------- Gypsids**

5. **An argillic (clay accumulation) or natric (high levels of illuvial clay and sodium) horizon -- Argids**
   These soils do not have a petrocalcic (cemented by calcium carbonate) horizon within a depth of 100 cm.

6. **A calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon within a depth of 100 cm -- Calcids**

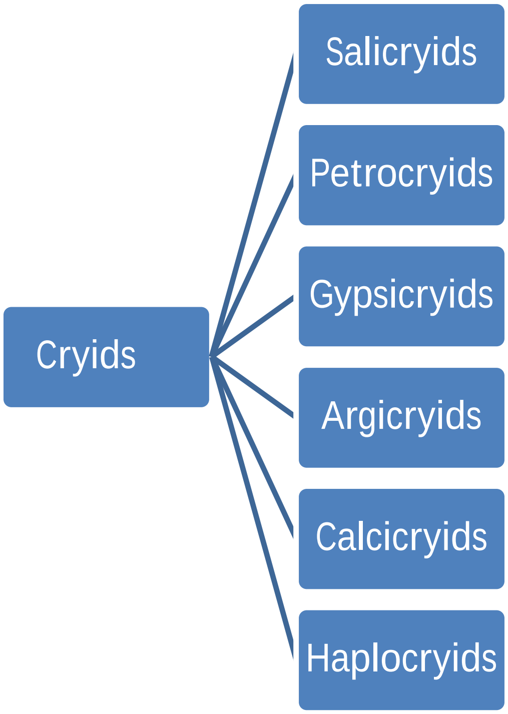
7. **A cambic (minimal soil development) horizon ------------------- Cambids**

Cryids Great Groups

Cryids are the Aridisols of cold deserts. Short growing seasons combined with arid conditions limit the use of these soils. The soils are characteristically at high elevations, dominantly in the mountain and basin areas in the United States and Asia and in other parts of the world.

The cold deserts commonly have undergone alternating periods of colder and warmer climates, which have resulted in the expansion and contraction of alpine glaciers in the adjacent mountains. The consequent variations in the sediment load carried by mountain streams have resulted in relict landforms, such as pediments, terraces, and alluvial fans. Cryids commonly show evidence of periglacial features, such as ice-wedged casts, ground wedges, and mounds.

Cryids may have a duripan (layer cemented by silica) or an argillic (clay accumulation), calcic (calcium carbonate accumulation), cambic (minimal soil development), gypsic (gypsum accumulation), natric (high levels of illuvial clay and sodium), petrocalcic (cemented by calcium carbonate), petrogypsic (cemented by gypsum), or salic (high content of salts) horizon. These horizons are the basis for the great groups. For example, Haplocryids are characterized by minimal development.



Key to Great Groups of Cryids (Back to key to suborders)

Cryids that have:

1. **A salic (high content of salts) horizon within a depth of 100 cm -- Salicryids**
2. **A cemented horizon within a depth of 100 cm ----------------- Petrocryids**
   This may be either a petrogypic horizon, petrocalcic horizon, or duripan.
3. **A gypsic (gypsum accumulation) horizon within a depth of 100 cm --- Gypsicryids**
4. **An argillic (clay accumulation) or natric (high levels of illuvial clay and sodium) horizon -- Argicryids**
5. **A calcic (calcium carbonate accumulation) horizon within a depth of 100 cm -- Calcicryids**
6. **A cambic (minimal soil development) horizon ---------------- Haplocryids**

Descriptions of Great Groups of Cryids

Salicryids—These soils have a salic (high content of salts) horizon. They can have other diagnostic horizons and characteristics, but the presence of soluble salts is considered important to interpretations. These soils occur in extremely arid, cold regions of the world. (Back to Cryids key)

Petrocryids—These soils have a cemented layer (a duripan or a petrocalcic or petrogypsic horizon). An argillic (clay accumulation), cambic (minimal soil development), or natric (high levels of illuvial clay and sodium) horizon may occur above the cemented layer. These soils occur in the mountains of Idaho and possibly Wyoming. (Back to Cryids key)

Gypsicryids—These soils have a gypsic (gypsum accumulation) horizon. A cambic (minimal soil development) horizon commonly occurs above the gypsic horizon. These soils formed in parent materials rich in gypsum. They are rare in the world. (Back to Cryids key)

Argicryids—These soils have an argillic (clay accumulation) or natric (high levels of illuvial clay and sodium) horizon in which silicate clays have accumulated. In general, the Argicryids without a natric horizon formed in areas of late-Pleistocene or older sediments or surfaces. Many of these soils receive inputs from dust, which may be a source of clay-sized particles. Argicryids may be on gentle or steep slopes. These soils are not extensive worldwide. (Back to Cryids key)

Calcicryids—These soils are derived from parent materials that have a high content of calcium carbonate or that have had calcium carbonate added as dust. Precipitation is unable to remove the calcium carbonate to substantial depths. These soils typically have a thin surface layer and a calcic (calcium carbonate accumulation) horizon. Some have a cambic (minimal soil development) horizon overlying the calcic horizon. (Back to Cryids key)

Haplocryids—These soils have a cambic (minimal soil development) subsoil horizon. A thin ochric (typically thin and/or light-colored) epipedon is common. Other diagnostic horizons may occur below a depth of 100 cm. These soils commonly have accumulations of calcium carbonate below the cambic horizon. They are rare in the world. (Back to Cryids key)

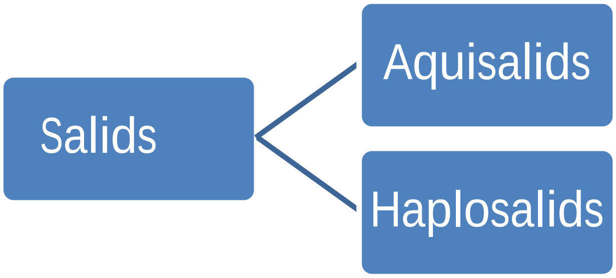
Salids Great Groups

Salids are most commonly in depressions (playas) in deserts or in closed basins in the wetter areas bordering deserts. In North Africa and the Near East, such depressions are referred to as sabkhas or chotts, depending on the presence or absence of surface water for prolonged periods. Click here to see a landscape dominated by Salids.

In an arid environment with hot temperatures, accumulation of salts commonly results when there is a supply of water soluble salts and a net upward movement of water in the soil. In some areas, a salic (high content of salts) horizon has formed in salty parent materials without the presence of ground water. The most common form of salt is sodium chloride (halite), but sulfates (thenardite, mirabilite, and hexahydrite) and other salts may also occur.

The concept of Salids is based on the accumulation of an excessive amount of salts that are more soluble than gypsum. As a rule, Salids are unsuitable for agricultural use, unless the salts are leached out. Leaching the salts is an expensive undertaking, particularly if there is no natural outlet for drainage water.

Two great groups are recognized. Aquisalids are saturated with water for 1 month or more during the year. Haplosalids are drier.



Profile of a Salid (specifically an Aquisalid). Salts are moving upward from the water table and accumulating in the salic horizon in the upper part of the profile and on the surface as a white salt crust.

(Back to Salids)

A landscape of Salids in Iran. As salt crystals accumulate and grow, they cause the soil surface to heave a few inches. This results in the large polygonal pattern and surface roughness. The low angle of the sun accentuates the surface pattern in this photo.

(Back to Salids)

Key to Great Groups of Salids (Back to key to suborders)

Salids that:

1. **Are saturated with water within a depth of 100 cm for 1 month or more annually --- Aquisalids**

2. **Are more or less freely drained ------------------------------------ Haplosalids**

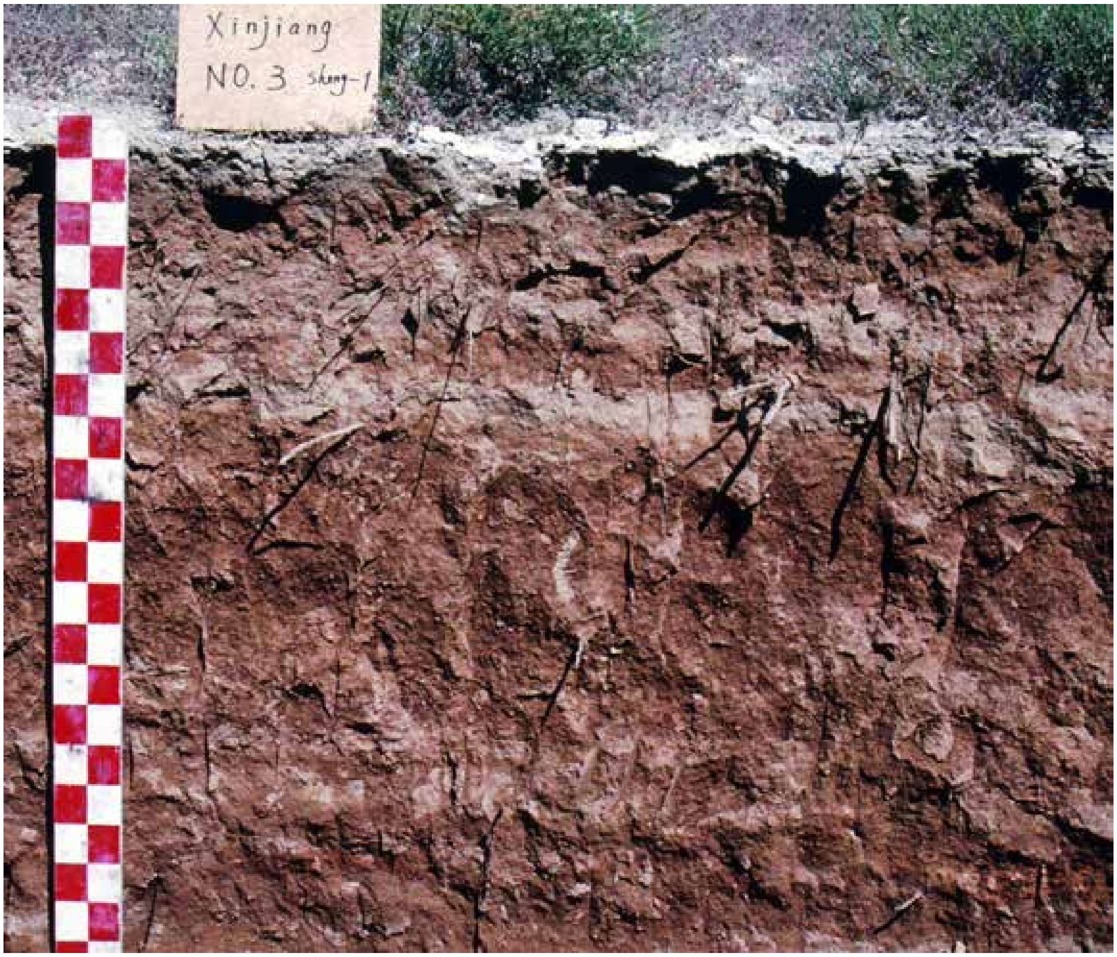
Descriptions of Great Groups of Salids

Aquisalids—These are salty soils in wet areas of deserts where capillary rise and evaporation of water concentrate the salts near the surface. Some of these soils have red and gray mottled color patterns (redoximorphic features) that result from saturation, reduction, and oxidation. In other soils, redoximorphic features may not be evident because of a high pH, which inhibits iron and manganese reduction. Aquisalids occur dominantly in depressional areas where they are saturated by ground water at least part of the year. The vegetation generally is sparse and consists of salt-tolerant shrubs, grasses, and forbs. Although these soils may be moist, the dissolved salt content makes them physiologically dry. (Back to Salids key)

Profile of an Aquisalid in the United Arab Emirates. This soil formed in marine deposits on coastal flats adjacent to the Arabian Gulf. This profile is highly saline and has a salic horizon throughout all parts visible in the photo. The white color of the upper 50 cm is due to an accumulation of the relatively rare soil mineral anhydrite, which is a form of gypsum that has lost water molecules from its chemical makeup. The upper 50 cm is an anhydritic horizon. Scale is in cm. (Photo courtesy of Dr. Shabbir A. Shahid)

Return to Aquisalids

Haplosalids—These soils have a high concentration of salts but do not have the saturation that is associated with Aquisalids. Haplosalids may be saturated for shorter periods than Aquisalids or may have had a water table associated with a past climate. In the Four Corners area of the United States, salic horizons have formed without the influence of a water table in saline parent materials. (Back to Salids key)



Profile of a Haplosalid in China. Salts are distributed throughout the profile and have accumulated in a white crust on the surface as a result of evaporation. Scale is in 10-cm increments.

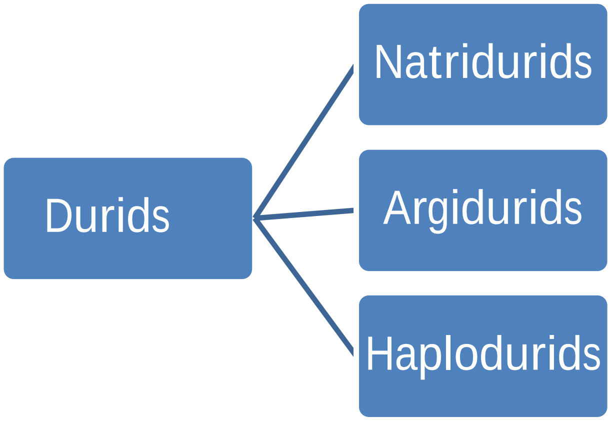
Return to Haplosalids

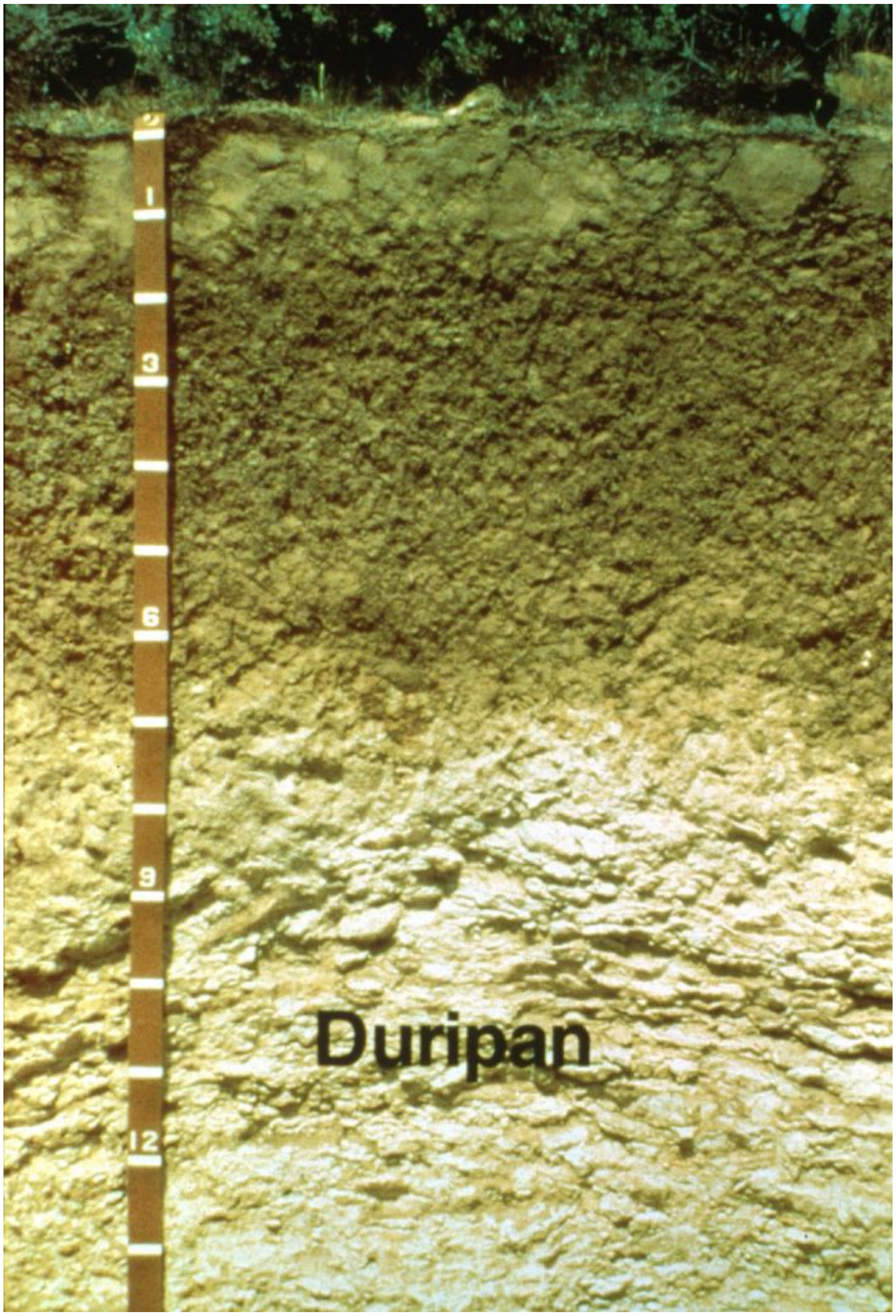
Durids Great Groups

Durids are the Aridisols that have a layer cemented by silica (duripan) that has an upper boundary within a depth of 100 cm. In many areas, the duripan is within a depth of 50 cm. These soils occur dominantly on gentle slopes and formed in sediments that contain pyroclastics. The duripan is cemented partly with opal or chalcedony. The soils commonly have accumulations of calcium carbonate. The duripan is a barrier to both roots and water.

Some Durids have an argillic (clay accumulation) or natric (high levels of illuvial clay and sodium) horizon above the duripan. These horizons are the basis for the great groups. Most of these soils are used for grazing. The amount of forage is low where the duripan is shallow.

Durids occur in the western part of the United States, particularly in Nevada.





Profile of a Durid (specifically a Haplodurid). The duripan begins at a depth of about 70 cm. Scale in decimeters.

(Back to Durids)

Key to Great Groups of Durids (Back to key to suborders)

Durids that have:

1. **A natric (high levels of illuvial clay and sodium) horizon above the duripan -- Natridurids**
2. **An argillic (clay accumulation) horizon above the duripan --- Argidurids**
3. **A cambic (minimal soil development) horizon above the duripan --- Haplodurids**
   A cambic horizon is common, but not required, in Haplodurids.

Descriptions of Great Groups of Durids

Natridurids—These soils have a natric (high levels of illuvial clay and sodium) horizon above the silica-cemented duripan. Commonly, the duripan is within a depth of 50 cm. In many areas it is plugged by calcium carbonate. These soils are commonly on gently sloping landscapes and formed in materials derived from pyroclastics. They are not extensive and are used mostly for grazing. (Back to Durids key)

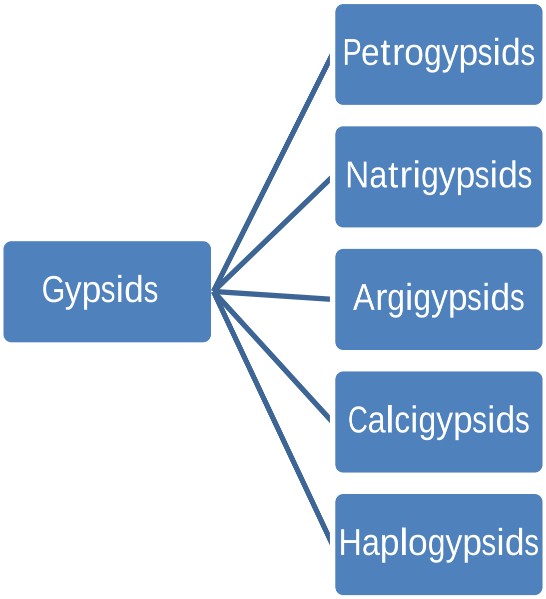
Argidurids—These soils have an argillic (clay accumulation) subsoil horizon above the duripan. Commonly, the duripan is within a depth of 50 cm. These soils are close to volcanic areas or formed in eolian or alluvial sediments derived from pyroclastics. (Back to Durids key)

Haplodurids—These soils have a cambic (minimal soil development) subsoil horizon above the silica-cemented duripan. Some have no diagnostic subsoil layer other than the duripan. These soils formed in materials with a pyroclastics influence. Most Haplodurids are used for grazing. (Back to Durids key)

Gypsids Great Groups

Gypsids are the Aridisols that have a gypsic (gypsum accumulation) or petrogypsic (cemented by gypsum) horizon within a depth of 100 cm. Accumulation of gypsum occurs initially as crystal aggregates in the voids of the soil. These aggregates grow by accretion, displacing the enclosing soil material. When the gypsic horizon occurs as a cemented impermeable layer, it is recognized as the petrogypsic horizon. Each of these forms of gypsum accumulation implies processes in the soil, and each presents a constraint to soil use. One of the largest constraints is caused by the dissolution of gypsum, which negatively affects structures, roads, and irrigation delivery systems.

The presence of a gypsic or petrogypsic horizon (or both), with or without other diagnostic horizons, defines the great groups of Gypsids. Gypsids occur in Iraq, Syria, Saudi Arabia, Iran, the United Arab Emirates, Somalia, West Asia, and arid areas in the western part of the United States. They occur on many segments of the landscape. Some of them have calcic (calcium carbonate accumulation) or related horizons that overlie the gypsic horizon.



Profile of a Gypsid (specifically a Haplogypsid) in New Mexico. This soil formed in gypsum-rich parent material. The white color is due primarily to the presence of gypsum throughout the profile. Scale is in cm. (Photo courtesy of Dr. David Weindorf)

Return to Gypsids

Key to Great Groups of Gypsids (Back to key to suborders)

Gypsids that have:

1. **A cemented horizon that has its upper boundary within a depth of 100 cm -- Petrogypsids**
   The cemented layer may be either petrogypsic or petrocalcic.

2. **A natric (high levels of illuvial clay and sodium) horizon within a depth of 100 cm -- Natrigypsids**

3. **An argillic (clay accumulation) horizon within a depth of 100 cm -- Argigypsids**

4. **A calcic (calcium carbonate accumulation) horizon within a depth of 100 cm --- Calcigypsids**

5. **A cambic (minimal soil development) horizon above the gypsic horizon --- Haplogypsids**
   A cambic horizon is common, but not required, in Haplogypsids.

Descriptions of Great Groups of Gypsids

Petrogypsids—These soils have a cemented layer (a petrogypsic or petrocalcic horizon) that has its upper boundary within a depth of 100 cm. These soils occur in very arid areas of the world where the parent material has a high content of gypsum. When the petrogypsic horizon is close to the surface, crusting forms pseudohexagonal patterns on the soil surface. Petrogypsids occupy old surfaces. In Syria and Iraq, they are on the highest terraces along the Tigris and Euphrates Rivers. They are also known to occur in western Texas and southern New Mexico. (Back to Gypsids key)

Profile of a Petrogypsid in Syria. This soil has a petrogypsic horizon beginning at a depth of about 85 cm and extending below the base of the photo. It is on an old geomorphic surface (high stream terrace). The petrogypsic horizon is a strong expression of pedogenic development. Scale is in 10-cm increments.

Return to Petrogypsids

Natrigypsids—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon within a depth of 100 cm. The gypsic horizon is commonly below the natric horizon. These soils formed in parent materials that had high contents of gypsum and sodium, such as sedimentary materials that were deposited in a marine environment or in closed basins. They are rare but are known to occur in the Four Corners area in the western part of the United States (northwestern New Mexico, northeastern Arizona, southeastern Utah, and southwestern Colorado). These soils are used primarily for grazing. (Back to Gypsids key)

Argigypsids—These soils have an argillic (clay accumulation) subsoil horizon above the gypsic horizon. They are known to occur in the Four Corners area in the western part of the United States and in New Mexico and Texas. They are used primarily for grazing. (Back to Gypsids key)

Calcigypsids—These soils have a calcic (calcium carbonate accumulation) subsoil horizon. Commonly, the calcic horizon is above the gypsic horizon because of differences in the solubility of gypsum and calcium carbonate. These soils are known to occur in Arizona, New Mexico, and Texas. Most Calcigypsids are used for grazing. (Back to Gypsids key)

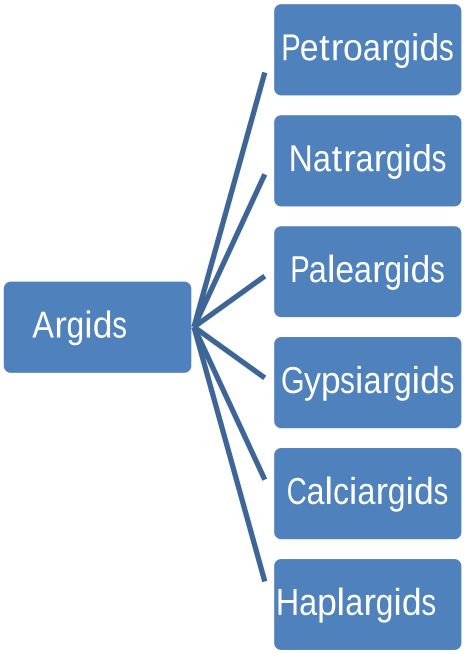
Profile of a Calcigypsid with an accumulation of both gypsum and calcium carbonate in the subsoil (white material below a depth of about 2 feet). The part with accumulation meets the criteria for both a gypsic and a calcic horizon. The right side of the profile has been smoothed; the left side shows the natural soil structure.

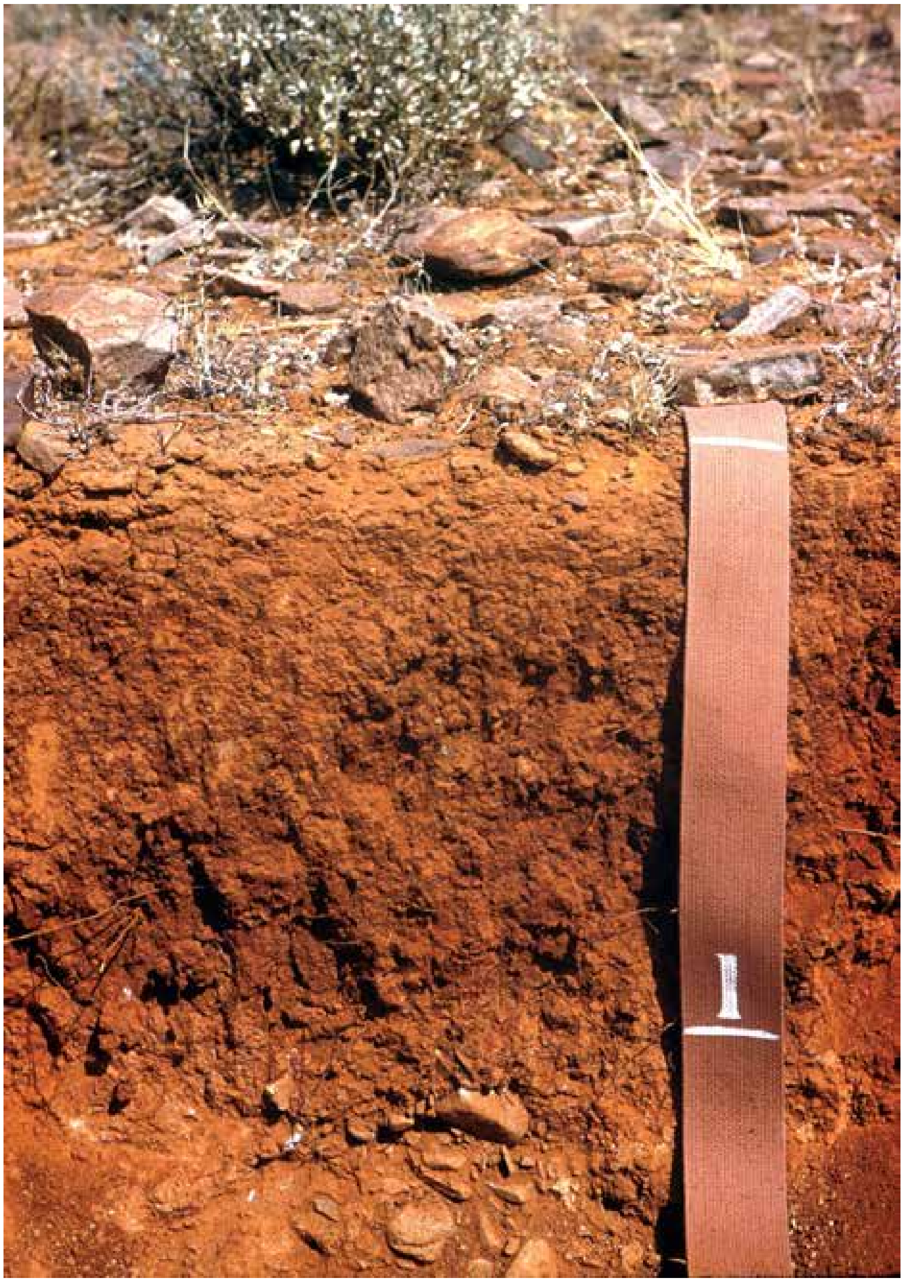
Return to Calcigypsids

Haplogypsids—Some Haplogypsids have a cambic (minimal soil development) subsoil horizon overlying the gypsic horizon. Others have only a gypsic horizon. Haplogypsids are commonly very pale in color. They are not extensive in the United States. The largest concentrations in the United States are in Arizona, Nevada, New Mexico, and Texas. These soils are more common in other parts of the world. (Back to Gypsids key)

Argids Great Groups

Argids are the Aridisols that have an argillic (clay accumulation) or natric (high levels of illuvial clay and sodium) horizon. In many Aridisols, the low water flux and high concentration of salts hinder clay illuviation. The presence of an argillic horizon is therefore commonly attributed to a moister paleoclimate (although there is evidence that clay illuviation occurred during the Holocene in arid soils). In semiarid areas (where the soil moisture regime grades to ustic or xeric), clay translocation commonly is more evident. Most Argids occur in North America. A few have been recognized in the deserts of North Africa and the Near East.





Profile of an Argid (specifically a Haplargid) in Australia. This soil has a relatively thin argillic horizon (darker colored area from depths of about 3 to 12 inches) in the upper part of the profile. Scale is in feet.

Return to Argids

Key to Great Groups of Argids (Back to key to suborders)

Argids that have:

1. **A cemented layer within a depth of 150 cm -------------------- Petroargids**
   The cemented layer may be a petrocalcic horizon, petrogypsic horizon, or duripan.

2. **A natric (high levels of illuvial clay and sodium) horizon --- Natrargids**

3. **Either:**

   a) An abrupt increase in clay content at the contact with, or within, the argillic horizon; OR

   b) A thick argillic (clay accumulation) horizon in which clay does not decrease significantly within a depth of 50 cm and that has mostly hue of 7.5YR or redder color in some part ----------------------- Paleargids
   For item a, the clay increase is ≥ 15% (absolute) over 2.5 cm. For item b, clay does not decrease by ≥ 20% relative to the maximum clay amount above. See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding color. Paleargids have no root-limiting layer within a depth of 50 cm.

4. **A gypsic (gypsum accumulation) horizon within a depth of 150 cm -- Gypsiargids**

5. **A calcic (calcium carbonate accumulation) horizon within a depth of 150 cm --- Calciargids**

6. **Only an argillic (clay accumulation) horizon ------------------- Haplargids**

Descriptions of Great Groups of Argids

Petroargids—These soils have a cemented layer (a duripan or a petrocalcic or petrogypsic horizon) that has its upper boundary at a depth between 100 and 150 cm. They occur on stable landscapes in the western part of the United States, in southern Argentina, and in western South Africa. (Back to Argids key)

Natrargids—These soils have a natric (high levels of illuvial clay and sodium) horizon that commonly has prismatic or columnar structure. They generally contain carbonates, soluble salts, or both. These soils formed in sediments that range in age from Holocene to late-Pleistocene. Most of them are nearly level to gently sloping. Natrargids occur in the western part of the United States and on the western edge of the Great Plains. (Back to Argids key)

Profile of a Natrargid. Due to its high sodium content and high level of illuvial clay, the subsoil meets the criteria for a natric horizon. Note the columnar structure capped with white silt coatings (beginning at a depth of about 6 inches) that is characteristic of many natric horizons. Scale is in inches (right) and cm (left).

Return to Natrargids

Paleargids—These soils are on stable land surfaces and have an abrupt textural change or a clay distribution in the argillic horizon that does not decrease significantly with increasing depth. Most of these soils formed in sediments appreciably older than late Pleistocene. If calcareous dust is present, some of these soils may be calcareous in all horizons. Slopes are typically gentle. (Back to Argids key)

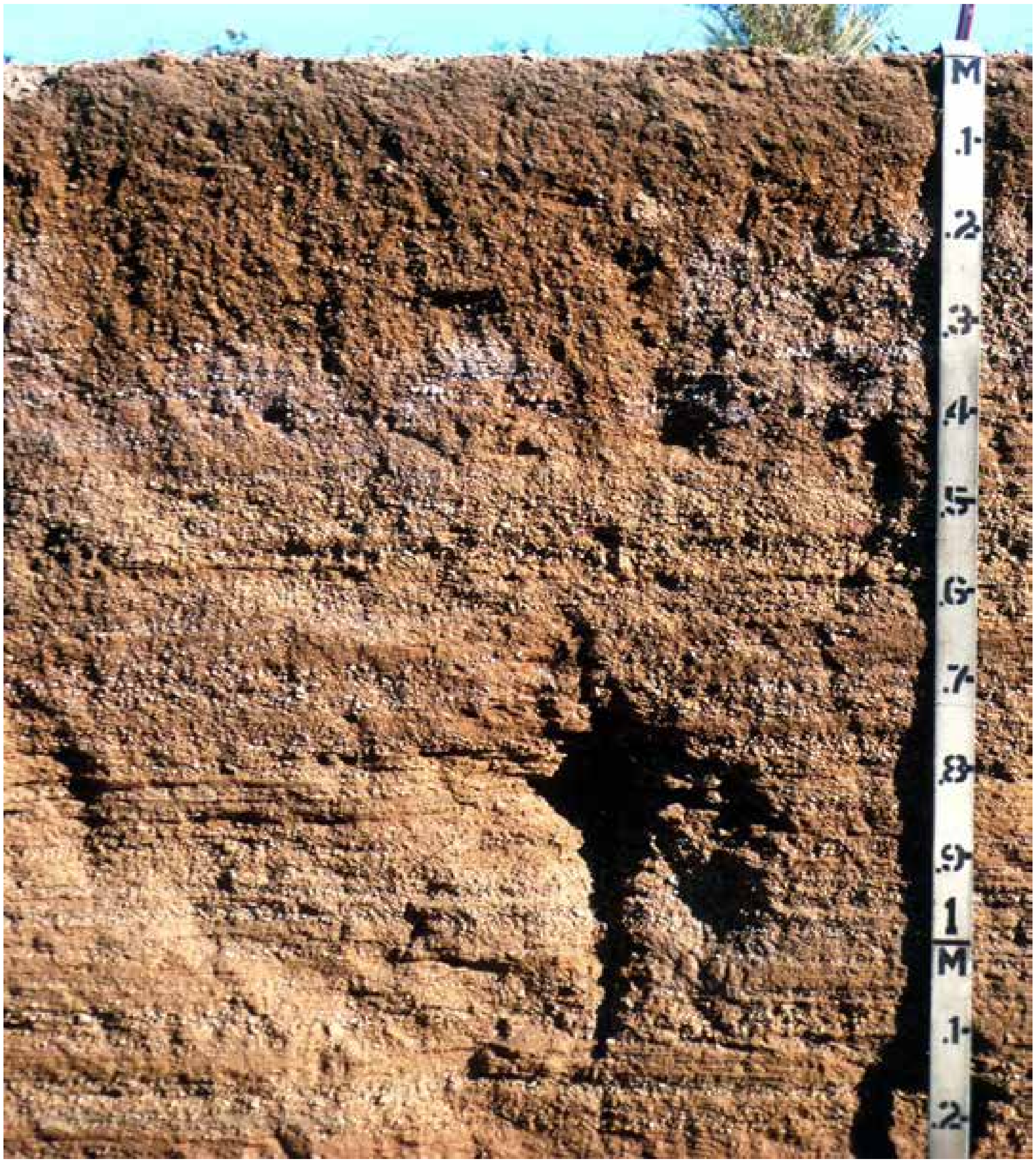
Gypsiargids—These soils have a gypsic (accumulation of gypsum) subsoil horizon within a depth of 150 cm. Most of these soils are on late-Pleistocene surfaces. In the United States, Gypsiargids are of minor extent and are known to occur in Arizona, New Mexico, and Texas. (Back to Argids key)

Calciargids—These soils have, below the clay-enriched argillic horizon, a calcic (calcium carbonate accumulation) horizon within a depth of 150 cm. Where the argillic horizon is calcareous, it is generally thought to have been recharged with calcium carbonate, possibly from dust, after the argillic horizon formed. Calciargids are commonly on late-Pleistocene erosional surfaces or on gentle to steep slopes. (Back to Argids key)

Profile of a Calciargid in New Mexico. The subsoil below a depth of about 40 cm consists of a clay-enriched argillic horizon (reddish brown) underlain abruptly by a calcic horizon (white) in which calcium carbonate has accumulated. The upper boundary of the calcic horizon is wavy, fluctuating between depths of about 80 and 110 cm. The profile has been smoothed on the right side; the natural soil structure is exposed on the left. The scale is in 20-cm increments (left) and feet (right).

Return to Calciargids

Haplargids—These soils have only an argillic (clay accumulation) horizon. They commonly have some calcium carbonate accumulations within or below the argillic horizon. Haplargids commonly occur on late-Pleistocene surfaces or sediments. (Back to Argids key)

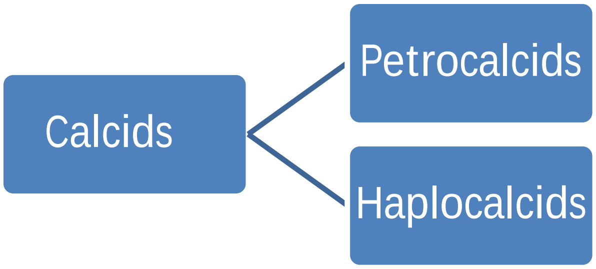


Profile of a Haplargid in New Mexico. The soil exhibits development only in about the upper 40 cm, where an ochric epipedon (between 0 and 10 cm) is underlain by an argillic horizon (10 to 40 cm). Below this depth, the soil retains the original stratified character of the alluvial deposits from which it formed. Scale is in 10-cm increments.

Return to Haplargids

Calcids Great Groups

Calcids are the Aridisols with accumulations of calcium carbonate that was in the parent materials or was added as dust, or both. Precipitation is insufficient to leach or move the carbonates to great depths. The upper boundary of the calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon is typically within a depth of 50 cm. If these soils are irrigated and cultivated, they typically have micronutrient deficiencies. Calcids are extensive in the western part of the United States and in other arid regions of the world.



Profile of a Calcid (specifically a Haplocalcid). The white color below a depth of about 30 centimeters is due to accumulations of calcium carbonate. Scale is in decimeters.

(Back to Calcids)

Key to Great Groups of Calcids (Back to key to suborders)

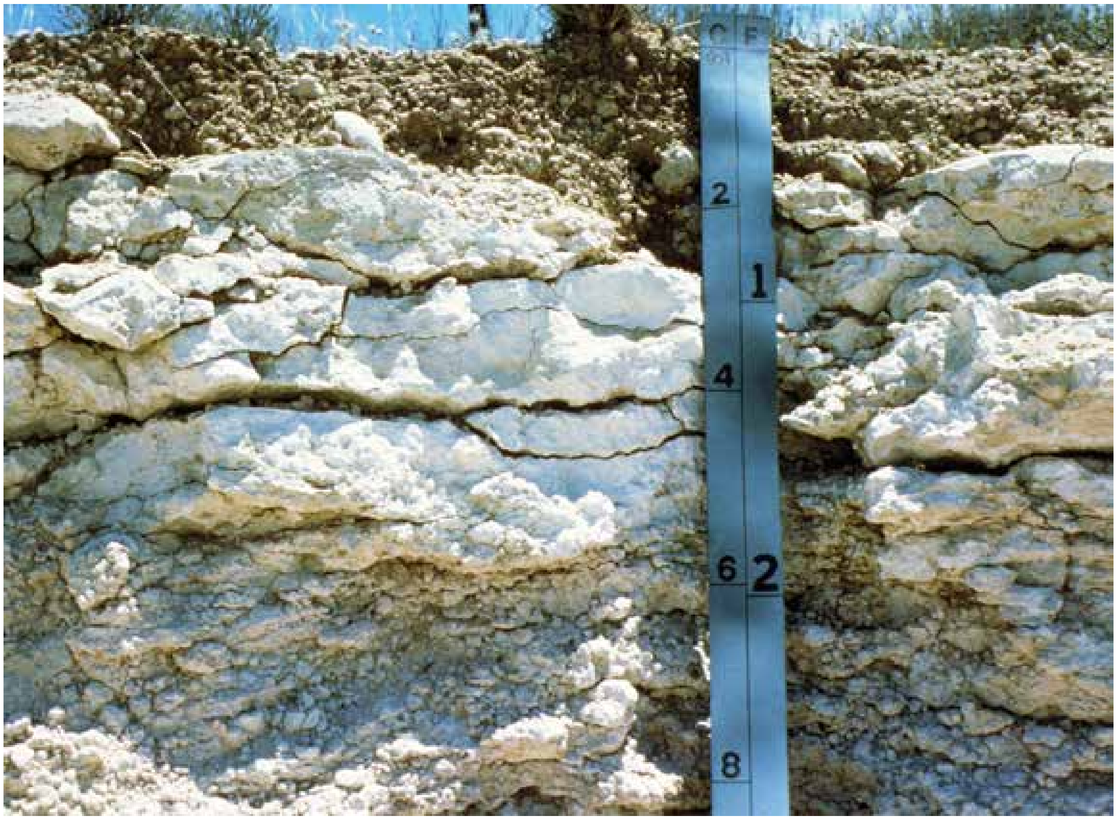
Calcids that have:

1. **A petrocalcic (cemented by calcium carbonate) horizon within a depth of 100 cm -- Petrocalcids**

2. **A calcic (calcium carbonate accumulation) horizon ------- Haplocalcids**

Descriptions of Great Groups of Calcids

Petrocalcids—These soils have a petrocalcic (cemented by calcium carbonate) subsoil horizon that has its upper boundary within a depth of 100 cm. Typically, the upper boundary of the petrocalcic horizon is close to the soil surface. Some of these soils show evidence of former argillic (clay accumulation) horizons that are now engulfed with carbonates. Generally, Petrocalcids are on gentle slopes that have been stable for long time periods. They occur on old landscapes in the southwestern part of the United States and in other deserts of the world. (Back to Calcids key)



Profile of a Petrocalcid in Texas. The white petrocalcic horizon below a depth of about 20 cm is very strongly cemented by an accumulation of calcium carbonate. Roots cannot penetrate this layer except in cracks. Scale is in 20-cm increments (left) and feet (right).

Return to Petrocalcids

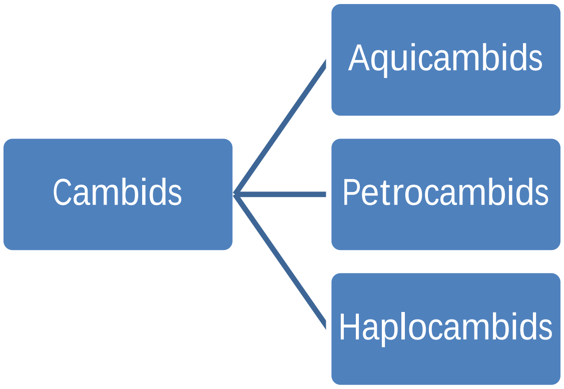
Haplocalcids—These soils have a calcic (calcium carbonate accumulation) subsoil horizon with its upper boundary within a depth of 100 cm. Some of these soils have a cambic (minimal soil development) horizon above the calcic horizon. Haplocalcids are extensive worldwide. (Back to Calcids key)

Profile of a Haplocalcid in Syria. The calcic horizon extends from a depth of about 30 cm to 70 cm. It is white due to an accumulation of calcium carbonate. The profile also has other salts. Note the thin, white salt crust on the surface caused by the evaporative upward movement of some of these salts. Scale is in 10-cm increments.

Return to Haplocalcids

Cambids Great Groups

Cambids are the Aridisols with the least degree of soil development. These soils have a cambic horizon within a depth of 100 cm. They may have other diagnostic horizons, such as petrocalcic (cemented by calcium carbonate), gypsic (gypsum accumulation), or calcic (calcium carbonate accumulation) horizons, but the upper boundary of these horizons is below a depth of 100 cm. Cambids are the most common Aridisols in the United States.



Profile of a Cambid (specifically a Haplocambid) in the United Arab Emirates. The cambic horizon extends from a depth of 10 cm to about 50 cm. Scale is in cm. (Photo courtesy of Dr. Craig Ditzler)

(Back to Cambids)

Key to Great Groups of Cambids (Back to key to suborders)

Cambids that have:

1. **Saturation with water within a depth of 100 cm for ≥ 1 month annually --- Aquicambids**
   Aquicambids may also be irrigated and have saturation and reducing conditions at a depth of ≤ 100 cm.

2. **A cemented layer within a depth of 150 cm ---------------- Petrocambids**
   The cemented layer may be a duripan, petrocalcic horizon, or petrogypsic horizon.

3. **A cambic (minimal soil development) horizon ------------ Haplocambids**

Descriptions of Great Groups of Cambids

Aquicambids—These soils are saturated with water for short periods in most years. They commonly are adjacent to playas and have accumulations of salts. Aquicambids commonly have high pH values, which inhibit the formation of red and gray mottled color patterns characteristic of wetness (redoximorphic features). (Back to Cambids key)

Petrocambids—These soils have a cemented layer (a duripan or a petrocalcic or petrogypsic horizon) that has its upper boundary at a depth between 100 and 150 cm. These soils are not extensive because most Aridisols have these diagnostic horizons at shallower depths. However, because Petrocambids indicate water movement, which is important in determining interpretations, classes for these types of soils are provided. (Back to Cambids key)

Haplocambids—Haplocambids are the most commonly occurring Cambids. These soils are characterized by minimal horizon expression. Most Haplocambids have a redistribution of carbonates below the cambic horizon. The amount of carbonates, however, is insufficient to meet the definition of a calcic horizon, or the upper boundary of the cambic horizon is more than 100 cm below the soil surface. A few of these soils have an anthropic (human-modified) epipedon. Haplocambids occur on a variety of landscapes, commonly on those younger than late Pleistocene. (Back to Cambids key)

Entisols Order

Entisols are young soils with little or no soil profile development.

General Characteristics

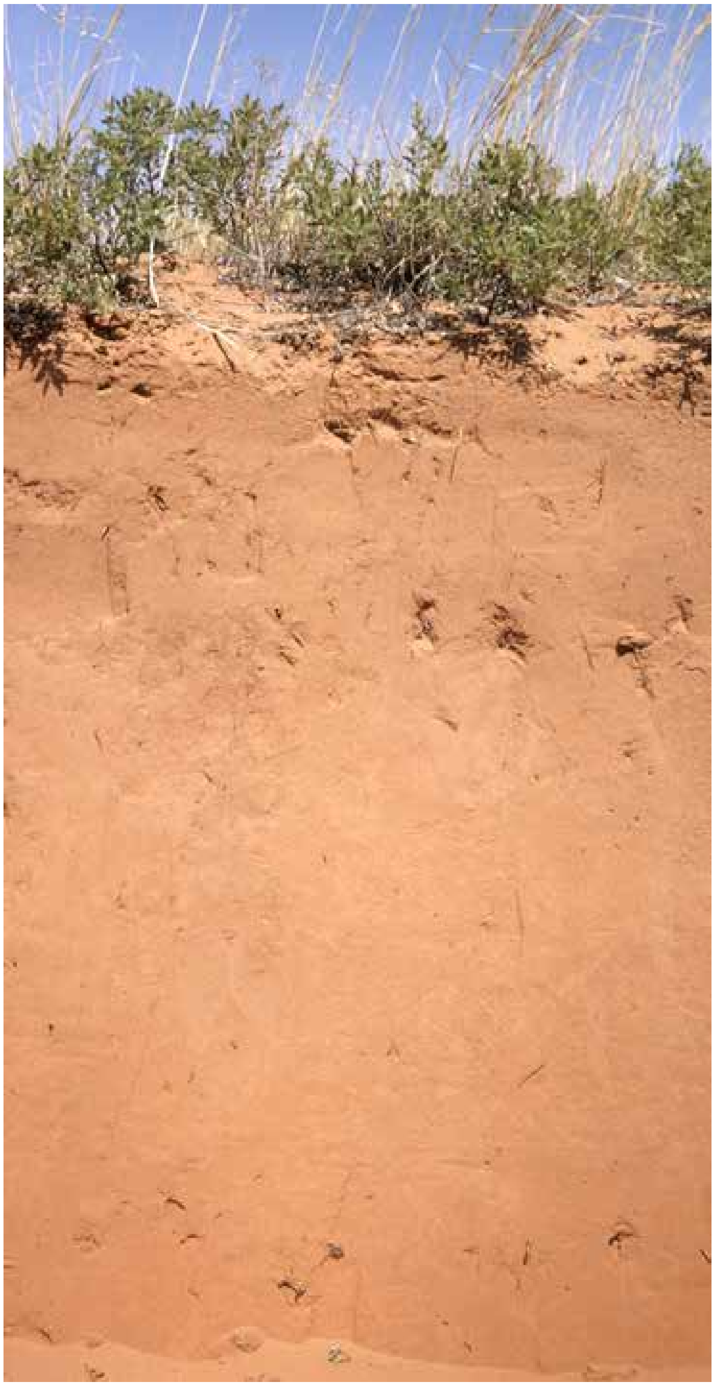
Entisols typically have little or no development of soil horizons, other than a slightly darkened ochric (typically thin and/or light-colored) epipedon as a surface layer. Therefore, these soils are characterized not by the kinds of horizons that have formed but rather by their minimal degree of soil development.

Environment and Processes

In many landscape positions where Entisols occur, the soil material has not been in place long enough for soil-forming processes to create distinctive horizons. Typical landscape settings include steep, actively eroding slopes, flood plains that receive new deposits of alluvium at frequent intervals, and shifting sand dunes. In general, Entisols are in landscape settings where processes of erosion or deposition are happening at rates faster than those needed for the formation of soil horizons. In some areas, Entisols occur in more stable landscape positions. In these areas, the soils consist mostly of quartz or other minerals that are resistant to the weathering needed to form soil horizons or the soil-forming processes are hindered by extreme environmental conditions.

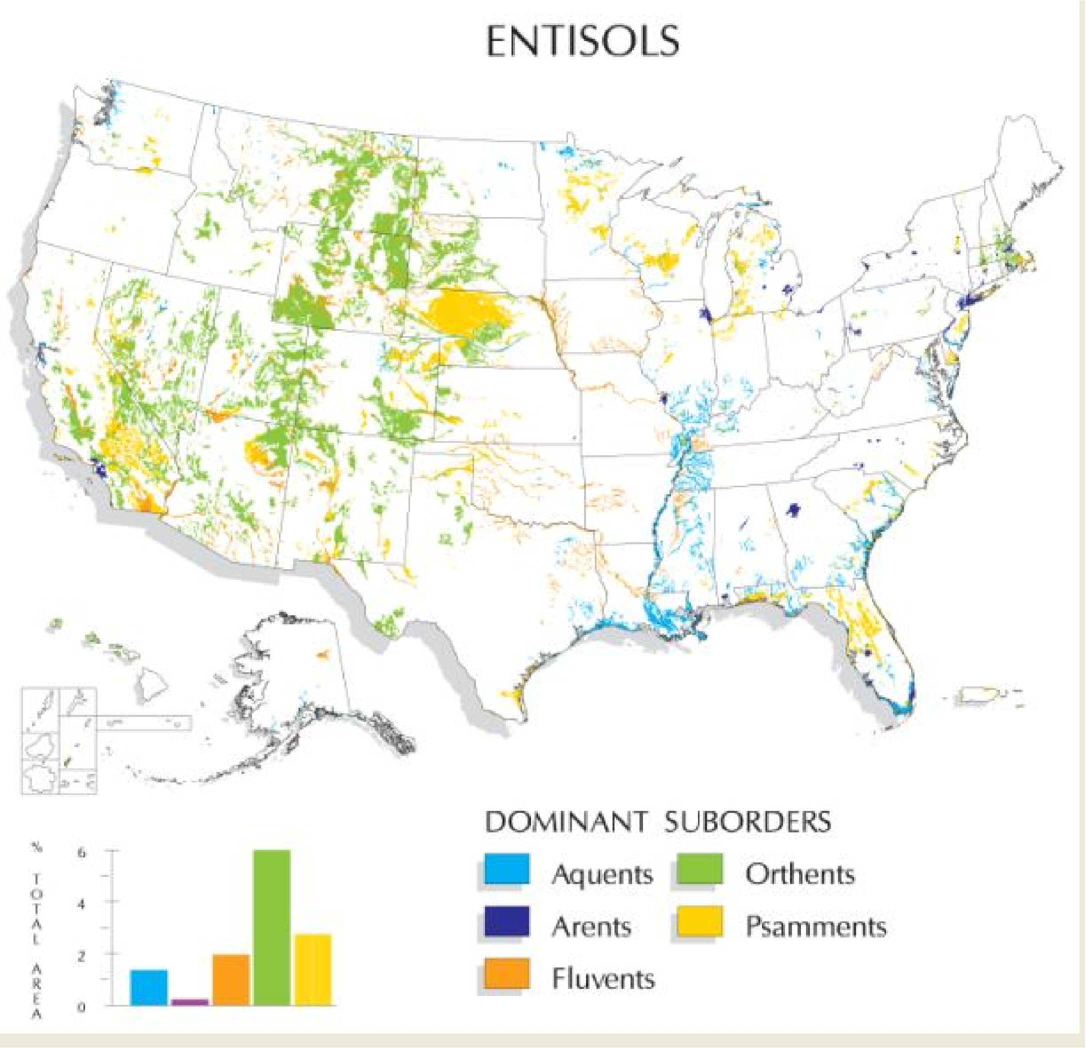
Location

Globally, Entisols occupy about 16% of the ice-free land area. They occur throughout the world in a wide range of ecological settings, ranging from the warm tropics into the cool higher latitudes. Entisols range from wet to dry areas and are common in many deserts of the world, especially in dune fields and on sand sheets. Entisols, especially those in rocky, coarse textured materials, are also on many steep mountain slopes, and they are found in shallow water areas, where they are permanently submerged (subaqueous soils). They have a wide range of parent materials and support many kinds of vegetation.

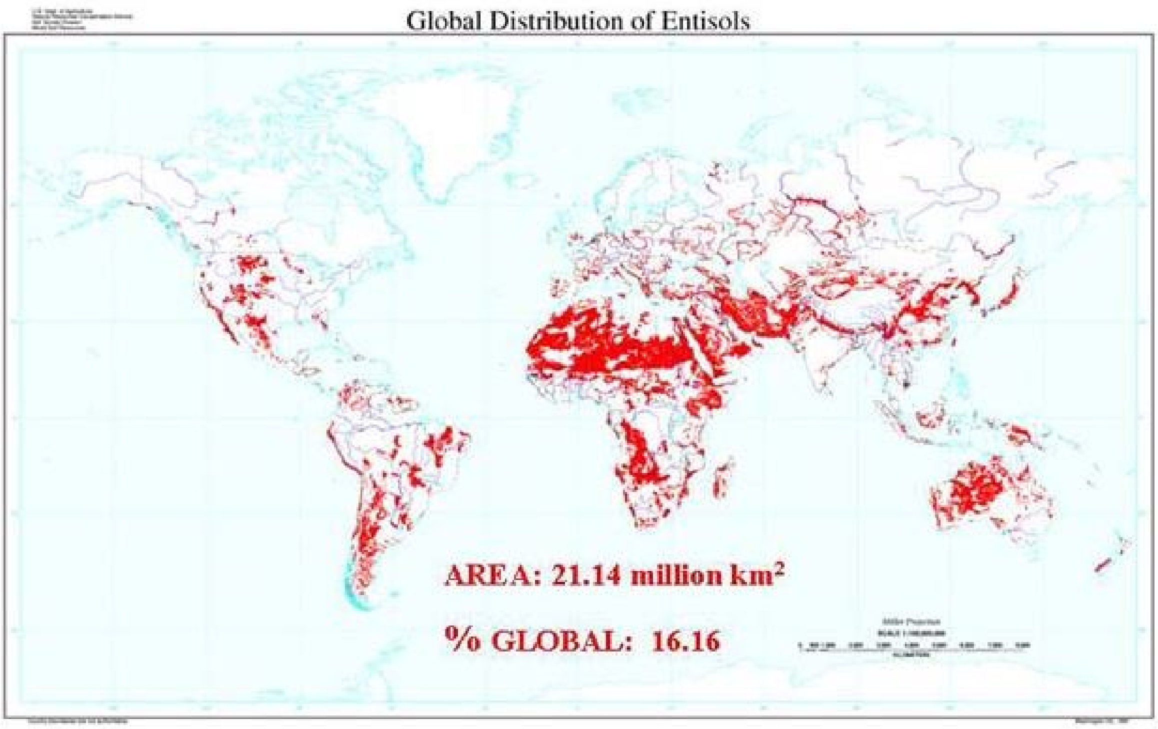


Profile of an Entisol.

(Back to Key to Soil Orders)



Entisols by suborder in the United States. Note: This map was produced before the introduction of the Wassents suborder and the elimination of the Arents suborder. Wassents are predominantly in shallow subtidal coastal bays and estuaries and in shallow (< 2.5 meters of overlying water) freshwater areas, such as lakes and ponds. Areas shown as Arents are now primarily included in Orthents.



Global distribution of Entisols.

Entisols Suborders

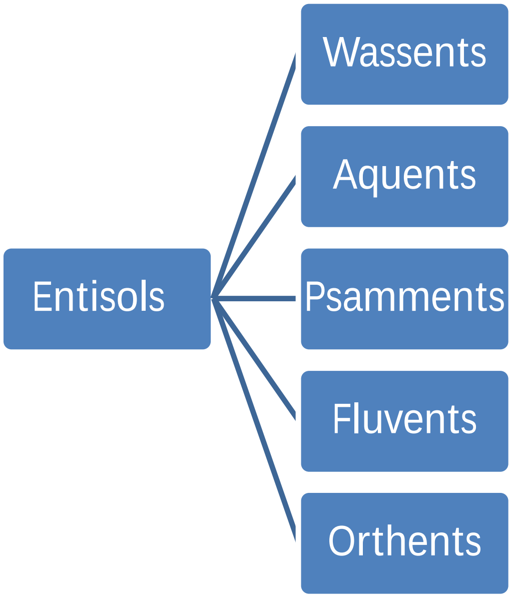
Classification of Entisols

In the definitions of the suborders, emphasis is divided between permanent inundation by water (Wassents); near surface saturation (Aquents); sandy texture (Psamments); formation in recent stratified alluvial sediments (Fluvents); and a virtual lack of horizon formation, mostly in areas of young erosional surfaces (Orthents).

The great groups of Wassents reflect those soils inundated by fresh water, those dominated by sandy textures, those containing sulfidic materials, those with a very low load-bearing capacity (high *n* value), those with an irregular decrease/increase in carbon content with increasing depth, and those with minimal evidence of soil development. The great groups within the other suborders reflects a combination of important properties, including moisture regime, cold soil temperature, patterns of soil saturation, and a dominance of resistant minerals making up the sand grains in sandy soils.

The five suborders are:

1. Wassents—Entisols that are permanently inundated with water
2. Aquents—wet Entisols (aquic conditions in the upper part)
3. Psamments—Entisols dominated by sandy textures
4. Fluvents—Entisols that formed in stratified alluvial sediments as evidenced by the irregular decrease/increase of carbon content with increasing depth
5. Orthents—other Entisols lacking in pedogenic development



Key to Suborders of Entisols

Entisols that:

1. **Are permanently inundated by water -------------------------------- Wassents**
   Wassents in tidal areas can be exposed to the atmosphere < 3 hours every day. Water is shallow enough to permit rooted vegetation to grow (generally less than 2.5 m).

2. **Have a seasonal high water table within a depth of 50 cm ---- Aquents**
   Artificially drained soils are included in Aquents. See 12th edition of "Keys to Soil Taxonomy" for specific details regarding required depths, presence of sulfidic materials, presence of a reduced matrix (soil exhibits color change upon exposure to air), and various texture/color combinations characteristic of Aquents.

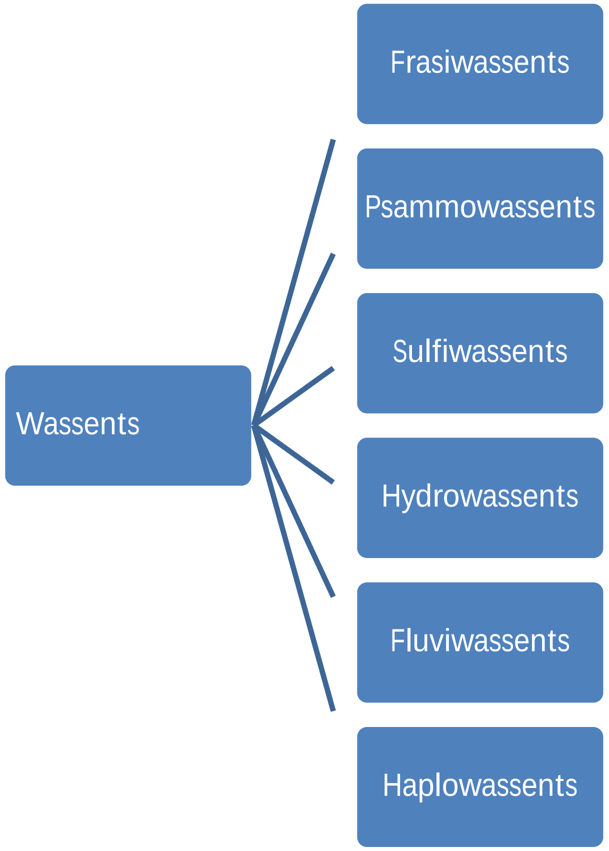
3. **Have sandy texture throughout the upper 100 cm ----------- Psamments**
   Psamments have < 35% rock fragments. Required depth of sandy textures is less in profiles with bedrock above 100 cm.

4. **Consist of stratified alluvial deposits and have an an irregular decrease/increase in carbon content with increasing depth -- Fluvents**
   Fluvents do not have 50 cm or more of human-transported material on the surface.

5. **Other simple Entisols (not included above) ----------------------- Orthents**

Wassents Great Groups

Wassents are Entisols that formed in shallow, permanently flooded environments. These soils are considered to have a subaqueous drainage class where there is a positive water pressure at the soil surface for more than 21 hours of each day in all years. The 21-hour minimum allows for short daily exposure of the soil surface in areas with large tidal fluctuations, such as coastal Maine in the United States. Some of these soils formed in coastal saltwater environments, while others formed in freshwater deposits. Most are known to occur in Holocene-age depositional environments from recent sedimentary deposits. Wassents have been found in all climates warmer than cryic and under submersed aquatic vegetation. These soils are important for wildlife habitat and aquaculture.



Profile of a Wassent exposed in a soil core from Rhode Island. Scale is in centimeters.

Eelgrass and other aquatic vegetation growing on a subaqueous soil.

(Back to Wassents)

Key to Great Groups of Wassents (Back to key to suborders)

Wassents that have:

1. **Low salinity levels -- Frasiwassents**
   The upper 100 cm has electrical conductivity of less than 0.2 dS/m in a 5:1, by volume, mixture (not extract) of water and soil.

2. **Sandy textures to a depth of 100 cm ------------------- Psammowassents**
   Texture is loamy fine sand or coarser, and rock fragments make up < 35%.

3. **Sulfidic materials (acid-producing, oxidizable sulfur compounds) within a depth of 50 cm --- Sulfiwassents**
   See 12th edition of "Keys to Soil Taxonomy" regarding depth and thickness requirements for sulfidic materials.

4. **A low load-bearing capacity (flows when compressed) --- Hydrowassents**
   See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding this property (including location in profile, clay content, and n *value).*

5. **Layers consisting of stratified alluvial deposits and an irregular decrease/increase in carbon content with increasing depth -- Fluviwassents**
   Fluviwassents cannot have human-transported material that is 50 cm or more thick on the surface.

6. **Moderate to high salinity and loamy or clayey textures --- Haplowassents**

Descriptions of Great Groups of Wassents

Frasiwassents—These soils formed in fresh water, in both natural and man-made water bodies. They have a low electrical conductivity (< 0.2 dS/m) in a 1:5 (by volume) soil:water ratio throughout the upper meter. Many of these soils have high levels of nutrients that support a large number of native and non-native vegetation. These soils are believed to be of large extent in the United States and are most extensive in mid to northern latitudes. (Back to Wassents key)

Psammowassents—These soils formed in salt or brackish water and have sandy textures of loamy fine sand or coarser throughout the upper meter. Psammowassents are commonly derived from Holocene sand on flood-tidal deltas and washover fans of coastal lagoons and shore face complexes. The fluidity class is nonfluid throughout the profile. Vegetation includes native algae, eelgrass, and widgeon grass. The soils are believed to be of large extent in the United States and are important for aquaculture. (Back to Wassents key)

Sulfiwassents—These soils formed in salt or brackish water and have sulfidic materials (acid-producing, oxidizable sulfur compounds) within the upper 50 cm. They typically have, in place, neutral pH values but, when exposed to air, are potentially extremely acid or ultra acid. Most Sulfiwassents will develop a sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon if they are artificially drained to an extent that oxygen is allowed to reach the sulfidic materials. Sulfiwassents are commonly derived from loamy and organic material in lagoon bottoms, barrier and mainland coves, shoals, and submerged wave-built terraces and are subject to minimal currents and wave action. Sulfiwassents are believed to be of large extent in the United States and are important for wildlife habitat and aquaculture. (Back to Wassents key)

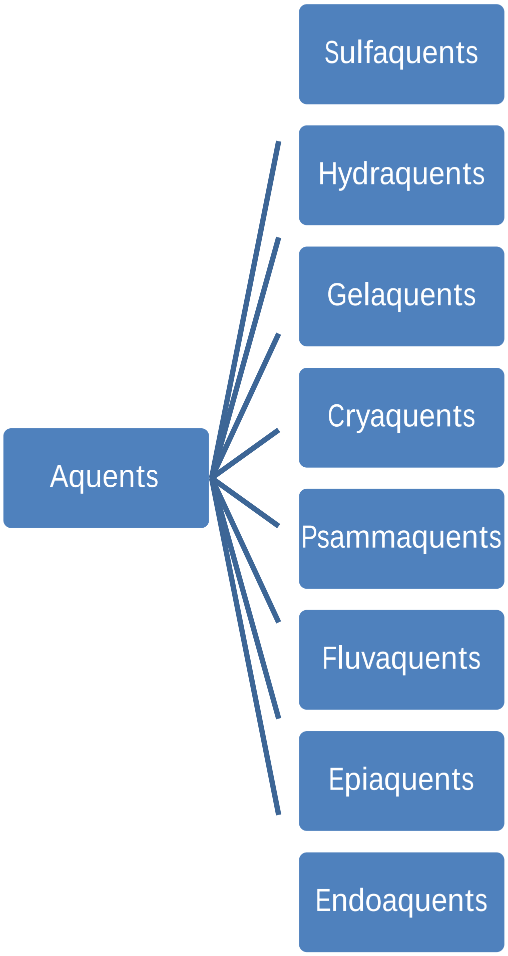
Hydrowassents—These soils formed in salt or brackish water and have a low load-bearing capacity, as evidenced by their slightly fluid or higher fluidity class, low bulk density, and clay content of more than 8%. The water content is high, and the soil strength is low. These soils are commonly derived from loamy and organic-rich mineral material in lagoon bottoms, barrier and mainland coves, and submerged stream valleys. They are subject to minimal currents and wave action. Hydrowassents are believed to be of large extent in the United States and are important for wildlife habitat and aquaculture. (Back to Wassents key)

Fluviwassents—These soils formed in salt or brackish water and have either an organic-carbon content of 0.2% or more at a depth of 125 cm or an irregular decrease/increase in organic carbon with increasing depth. Fluviwassents are commonly derived from Holocene sand in salt or brackish water on washover fans, submerged-upland tidal marsh, and submerged wave-built terraces. These soils are subject to severe storm events and strong wave action. Vegetation includes native algae, eelgrass, and widgeon grass. Fluviwassents are believed to be of large extent in the United States and are used as wildlife habitat, for aquaculture, and for recreation. (Back to Wassents key)

Haplowassents—These soils formed in salt or brackish water and have loamy textures finer than loamy fine sand. These soils are commonly derived from coarse textured deposits of sand and gravel. Haplowassents have a high load-bearing capacity and are potential ground-water discharge areas. Vegetation includes native algae and eelgrass. These soils are believed to be of large extent in the United States and are important to aquaculture. (Back to Wassents key)

Aquents Great Groups

Aquents are the wet Entisols. They are saturated close to the surface for a long enough period during the year to become devoid of oxygen (aquic conditions). Some are artificially drained. Aquents commonly occur in wetlands, such as in tidal marshes, on deltas, on the margins of lakes (where the soils are continuously saturated with water), on flood plains along streams (where the soils are saturated at some time of the year), and in areas of wet, sandy deposits. Many Aquents have bluish or grayish colors and redoximorphic features (gray and red color patterns). They may have any temperature regime. Most of them formed in recent sediments and support vegetation that tolerates permanent or periodic wetness.



Profile of a somewhat poorly drained Aquent (specifically a Fluvaquent) in Germany. The soil is on a flood plain and formed in loamy alluvial deposits. The profile shows little soil development apart from the gray colors due to periodic saturation and reduction. The right side of the profile shows the natural soil structure; the left side has been smoothed. Scale is in cm.

Return to Aquents

Key to Great Groups of Aquents (Back to key to suborders)

Aquents that have:

1. **Sulfidic materials (acid-producing, oxidizable sulfur compounds) within a depth of 50 cm --- Sulfaquents**
   See 12th edition of "Keys to Soil Taxonomy" for information regarding depth and thickness requirements for sulfidic materials.

2. **A low load-bearing capacity (fluid when compressed) --- Hydraquents**
   See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding this property (such as location in profile, clay content, and n *value).*

3. **Very cold average soil temperature ------------------------------ Gelaquents**
   These soils have a gelic soil temperature regime.

4. **Cold average soil temperature ------------------------------------ Cryaquents**
   These soils have a cryic soil temperature regime.

5. **Sandy textures to a depth of 100 cm ----------------------- Psammaquents**
   Texture is loamy fine sand or coarser throughout the upper meter, and rock fragments make up < 35%.

6. **Layers consisting of stratified alluvial deposits, with an irregular decrease/increase in carbon content with increasing depth -- Fluvaquents**
   Fluvaquents do not have 50 cm or more of human-transported material on the surface. Slope is < 25%.

7. **Episaturation (perched water table) ----------------------------- Epiaquents**

8. **Endosaturation (saturated throughout the profile) -------- Endoaquents**

Descriptions of Great Groups of Aquents

Sulfaquents—These soils have an appreciable amount of sulfides close to the soil surface and have few or no carbonates. The sulfides are close enough to the surface for the soils to become extremely acid and virtually sterile if drained. Sulfaquents are largely restricted to coastal marshes where the water is brackish. Tidal marshes at the mouth of rivers normally have areas of these soils unless the river sediments are rich in carbonates. Coastal marshes that are not near rivers also may have areas of these soils if storms periodically flood them with salt water. Sulfaquents are permanently saturated at or near the surface, and many are nearly neutral in reaction. They commonly have a low load-bearing capacity because they tend to behave like a fluid when compressed (the *n* value typically is high, commonly more than 1 in most horizons). A histic epipedon (wet, organic surface layer) is common. Sulfaquents commonly are not used as cropland, but some are used for the production of rice. The areas used for rice are kept flooded at all times, except for a very brief period while the crop is harvested. Sulfaquents are extensive along coasts and bays, ranging from the Equator to high latitudes. They are moderately extensive on the east coast of the United States, where they border the Atlantic Ocean in areas not protected by barrier islands. (Back to Aquents key)

Hydraquents—These are loamy and clayey soils that formed in sediments that were deposited under water and are now permanently saturated with water. Hydraquents never have been dry. Consequently, the bulk density is low (commonly about 0.6 g/cc) and the water content is very high (commonly more than 100% of the dry weight). Because of the high water content, soil strength is commonly too low to support grazing animals. If the soils are drained, the loss of water is irreversible and the bulk density increases as water is withdrawn. The soils typically have a reduced matrix (exhibit color change on exposure to air), and their colors mostly are bluish gray to greenish gray and change to shades of brown when the soils are exposed to air. A color change normally can be seen within a matter of seconds or a few minutes but may not be complete until some weeks have passed. Hydraquents are extensive in tidal marshes. In the United States, they are largely confined to the Atlantic and Gulf coasts, although a few are on the northern Pacific coast and near San Francisco Bay (Back to Aquents key)

Gelaquents—These are the Aquents of very cold regions. They have a gelic soil temperature regime but lack permafrost within the soil profile. They are subject to wide variations in summer high temperatures and winter low temperatures, which result in mean annual soil temperatures of 0 degrees C or less, but without permafrost. These soils tend to have a high content of rock fragments, and some are shallow to bedrock. (Back to Aquents key)

Cryaquents—These are the cold, wet soils in high mountains or of high latitudes. Cryaquents are on flood plains, in depressional areas, and in coastal marshes. Many are grayish and stratified. Those in coastal marshes commonly have greenish to bluish hues. Because they are both cold and wet, Cryaquents have a low potential for farming. These soils formed in recent sediments. The major areas of these soils in the United States are in Alaska. In Alaska, Cryaquents are extensive south of the permafrost zone and occur in coastal marshes, on outwash plains, and on flood plains. Most Cryaquents support mixed forest, shrub, or grassy vegetation. Many are nearly level, and their parent materials are typically Holocene or late-Pleistocene sediments. (Back to Aquents key)

Psammaquents—These soils have a sandy texture and commonly are gray, with or without redoximorphic concentrations (reddish to black accumulations of iron-manganese oxides). Most of these soils formed in late-Pleistocene to recent sediments. Most do not have distinctive features, but a few have a weakly developed subsoil horizon that is similar to the one in Spodosols. Others show some darkening and accumulation of organic matter in the surface layer. (Back to Aquents key)

Fluvaquents—These are primarily the stratified, wet soils on flood plains and deltas of mid and low latitudes. The stratification reflects the deposition of sediments under changing currents and in shifting channels. The sediments are of Holocene age. Fluvaquents have a relatively high content of organic carbon at a considerable depth when compared with many other wet, mineral soils. Because the materials have dried or have partially dried from time to time as they accumulated, they are not fluid when wet. Fluvaquents are extensive along large rivers, particularly in humid areas. Generally, these soils are nearly level. Many support either a deciduous or coniferous forest. Some have been cleared and protected from flooding and are used as cropland or pasture. (Back to Aquents key)

Profile of a poorly drained Fluvaquent used for growing rice in South Korea. The upper 20 cm of soil material has been added to the soil to improve production. The gray colors below about 45 cm are due to prolonged seasonal saturation of the soil by a water table. In 1984, this location held the world record for rice production with 10.4 tons per acre. Scale is in 10-cm increments.

Return to Fluvaquents

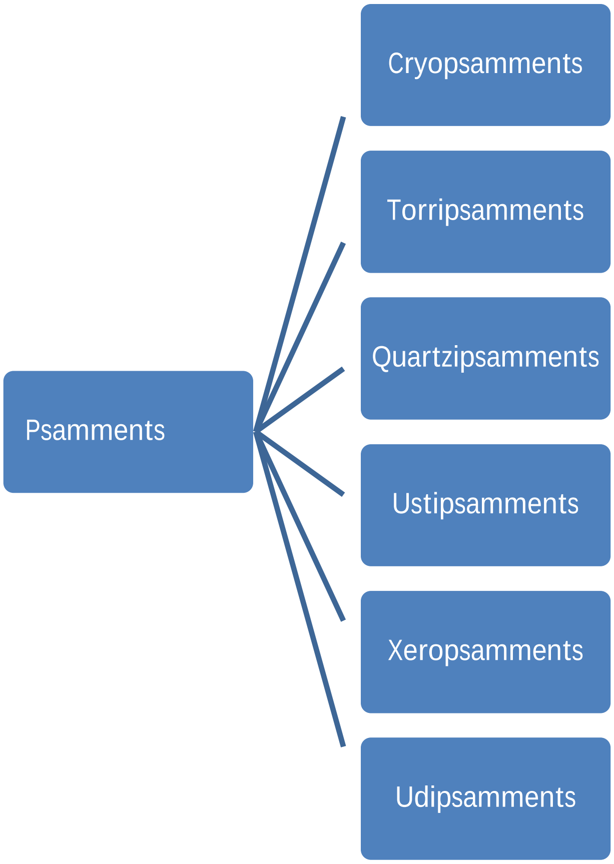
Epiaquents—These soils have ground water that is perched during some periods and fluctuates from a level near or above the soil surface in wet seasons. Many Epiaquents support either a deciduous or coniferous forest. Some have been cleared and are used as cropland or pasture. Epiaquents are generally nearly level, and their parent materials are typically late-Pleistocene or Holocene sediments. (Back to Aquents key)

Endoaquents—These soils are saturated throughout the profile for some time during the year. Many Endoaquents support either a deciduous or coniferous forest. Some have been cleared and are used as cropland or pasture. Endoaquents are generally nearly level, and their parent materials are typically late-Pleistocene or Holocene sediments. (Back to Aquents key)

Psamments Great Groups

Psamments are the sandy Entisols with < 35% rock fragments. They are sandy in all layers, generally to a depth of 100 cm or more. Some formed in poorly graded (well sorted) sands on shifting or stabilized sand dunes, in cover sands, or in sandy parent materials that were sorted in an earlier geologic cycle. Some formed in sands that were sorted by water and are on outwash plains, lake plains, natural levees, or beaches. A few Psamments formed in material weathered from sandstone or granitic bedrock. Psamments occur in any climate, but they cannot have permafrost within a depth of 100 cm. They can have any vegetation and are on surfaces of virtually any age, from recent historic to Pliocene or older. The Psamments on old stable surfaces commonly consist of quartz sand. The depth to ground water typically is more than 50 cm and commonly much more.

Psamments have a relatively low water-holding capacity. Those that are bare and become dry are subject to soil blowing and drifting and cannot easily support wheeled vehicles. Because very gravelly sands do not have the two qualities just described, they are excluded from Psamments and are grouped with Orthents. Thus, not all Entisols that have a sandy texture are Psamments.



Profile of a Psamment (specifically a Quartzipsamment). This particular profile has lamellae (thin clay-enriched lateral bands) below a depth of about 90 cm. Scale is in 10-cm increments. (Photo courtesy of John Kelley)

Return to Psamments

Key to Great Groups of Psamments (Back to key to suborders)

Psamments that have:

1. **Cold average soil temperature ------------------------------- Cryopsamments**
   These soils have a cryic soil temperature regime.

2. **Inadequate soil moisture available for crop growth --- Torripsamments**
   These soils have an aridic (torric) soil moisture regime.

3. **Sand grains dominated by quartz and other minerals that are highly resistant to weathering ------------------------------------- Quartzipsamments**
   These soils have > 90% (by weighted average) resistant minerals.

4. **Somewhat limited soil moisture available for crop growth -- Ustipsamments**
   These soils have an ustic soil moisture regime. Moisture is limited, but available, during portions of the growing season.

5. **A Mediterranean-type climate -------------------------------- Xeropsamments**
   These soils have a xeric soil moisture regime (cool and moist in winter and warm and dry in summer).

6. **Seasonally well-distributed precipitation ------------------ Udipsamments**
   These soils have a udic soil moisture regime.

Descriptions of Great Groups of Psamments

Cryopsamments—These are the Psamments of cold areas. In the United States, they are primarily in the high mountains of the West and in Alaska. Generally, they have, or had before they were disturbed, coniferous forest vegetation. They are of small extent. Most of them formed in material weathered from granitic rocks or in deposits of late-Pleistocene or recent age. Some formed in recent volcanic deposits. (Back to Psamments key)

Torripsamments—These are the cool to hot Psamments of arid climates. They have an aridic (or torric) moisture regime. Many of these soils are on stable surfaces, some are on dunes, some are stabilized, and some are moving. Torripsamments consist of quartz, mixed sands, volcanic glass, or even gypsum and may have any color. Generally, they are neutral or calcareous and are nearly level to steep. The vegetation consists mostly of xerophytic shrubs, grasses, and forbs. Many of these soils support more vegetation than other soils with an aridic moisture regime, presumably because rapid infiltration results in little or no precipitation being lost to runoff. Some of the soils on dunes support a partial cover of xerophytic and ephemeral plants. The shifting dunes may be devoid of plants in most years. Most of the deposits are of late-Pleistocene or younger age. These soils are used mainly for grazing. They are extensive in many deserts around the world, including areas in the western United States. (Back to Psamments key)

Profile of a Torripsamment in New Mexico. This soil formed in windblown sands and exhibits only minimal soil profile development. Its only diagnostic horizon is a thin, very slightly darkened ochric epipedon that is at the surface and only a few cm thick. Note the light-colored recently deposited aeolian sand collecting between plants. Scale is in feet (right) and 10-cm increments (left).

Return to Torripsamments

Quartzipsamments—These are the freely drained Psamments that have more than 90% resistant minerals. They are in humid to semiarid, cool to hot regions. These soils have a high content of quartz sand and are white or stained in shades of brown, yellow, or red. Because they have virtually no minerals that can weather, they can occur on some extremely old land surfaces. They also occur on late-Pleistocene and younger surfaces. The vegetation on Quartzipsamments varies widely depending on climate. In cultivated areas, supplemental water and nutrient needs can be high. Quartzipsamments are extensive on the coastal plains of the United States.

(Back to Psamments key)

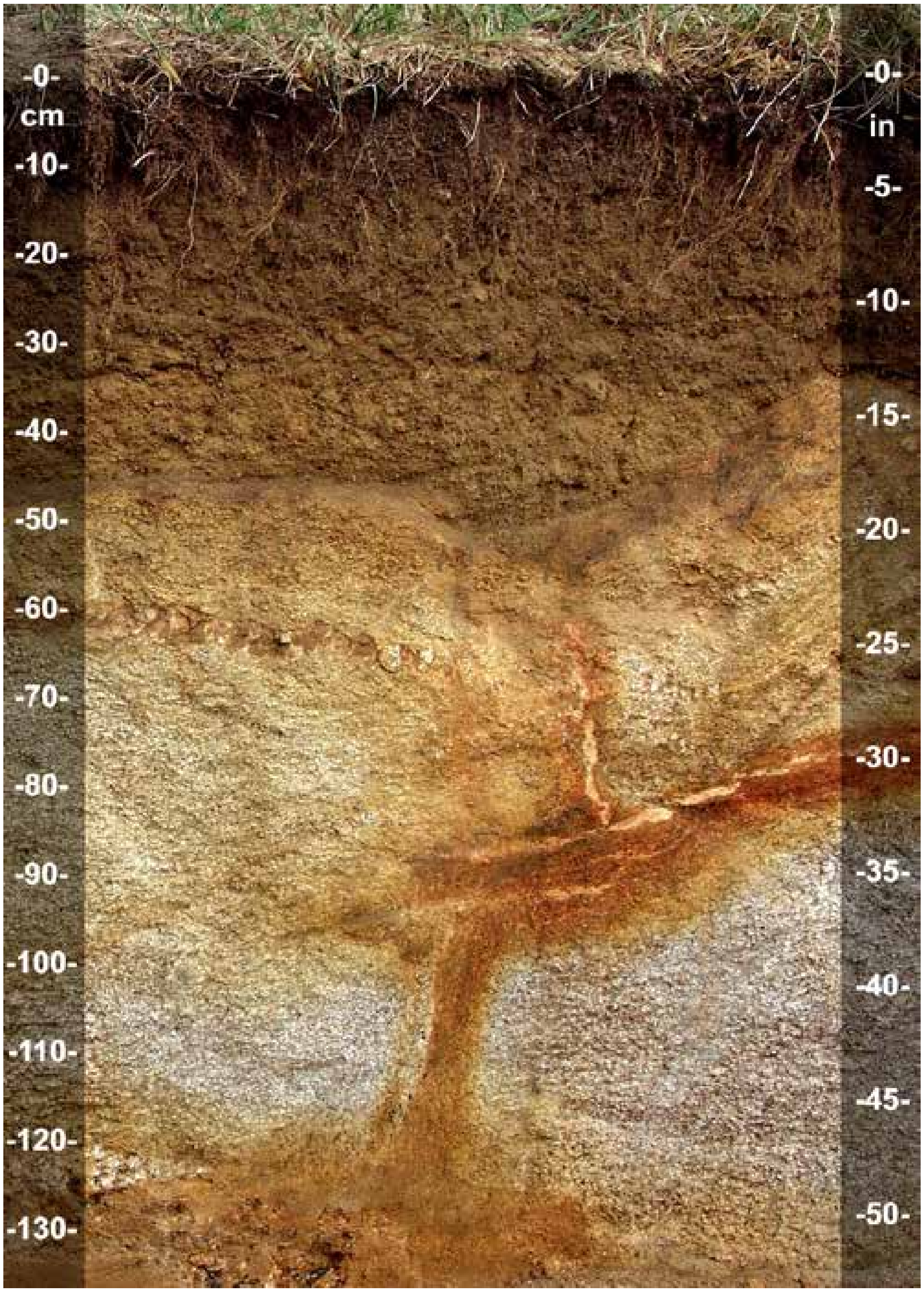
Profile of a Quartzipsamment in Florida. This soil has an ochric epipedon about 18 cm thick and no other diagnostic horizon. Below the ochric epipedon is sand dominated by quartz minerals, which give the profile its light color. Because quartz grains are resistant to weathering processes, Quartzipsamments have little inherent capacity for further profile development. Small amounts of finer material have been leached downward and can be seen as thin lamellae below a depth of about 170 cm. Scale is in cm.

Return to Quartzipsamments

Ustipsamments—These are the Psamments that have an ustic moisture regime. Although moisture is limited, it is generally available during portions of the growing season. Temperatures range from cool to hot. These soils support mostly grass or savanna vegetation. A few are in drought-tolerant forests of small, scattered trees. Many support as much or more vegetation as other soils with an ustic moisture regime, perhaps because rapid infiltration results in little or no precipitation being lost to runoff. Ustipsamments are used mainly for grazing. Few of them are cultivated because they are subject to soil blowing if cultivated. Ustipsamments are extensive on the Great Plains of the United States. (Back to Psamments key)

Xeropsamments—These are the Psamments of Mediterranean-type climates, where they are moist in winter and dry in summer. Temperatures range from cool to hot. Most Xeropsamments formed in deposits of late-Wisconsinan or more recent age. Some are on terraces and glacial outwash plains. Others are on dunes. Because the supply of winter moisture is reliable, few of the dunes are shifting. Some of these soils have supported coniferous vegetation, but most have supported and still support a mixture of grasses and xerophytic shrubs or trees. Xeropsamments are moderately extensive in parts of the western United States. (Back to Psamments key)

Udipsamments—These are the Psamments of humid regions. Precipitation is distributed throughout the year. These soils are predominantly in areas of late-Pleistocene or more recent deposits and are mostly brownish and freely drained. Most have supported forest vegetation, but a few have been cultivated ever since the sands were deposited. Others have been cultivated for a very long time. Udipsamments are extensive in the United States. Many are used as forest. Large areas of these soils, mostly where they have moderate to hot temperature regimes, have been cleared and are used as cropland or pasture. (Back to Psamments key)

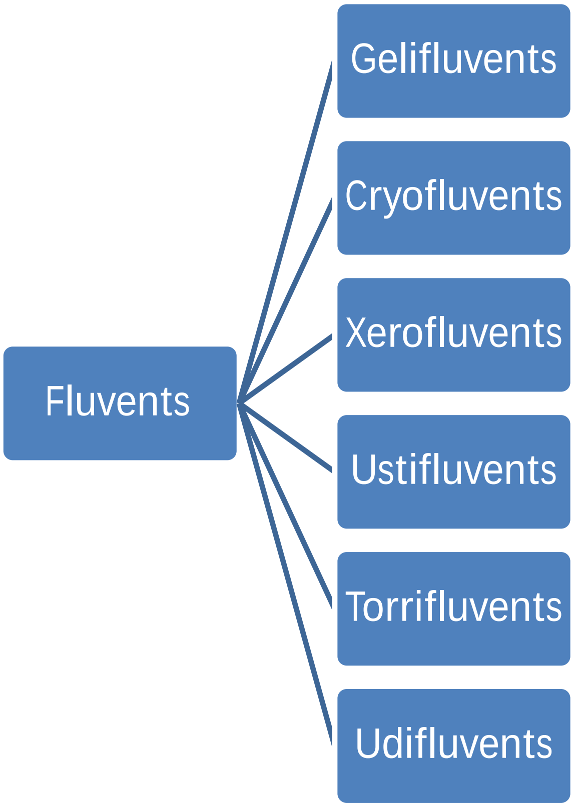


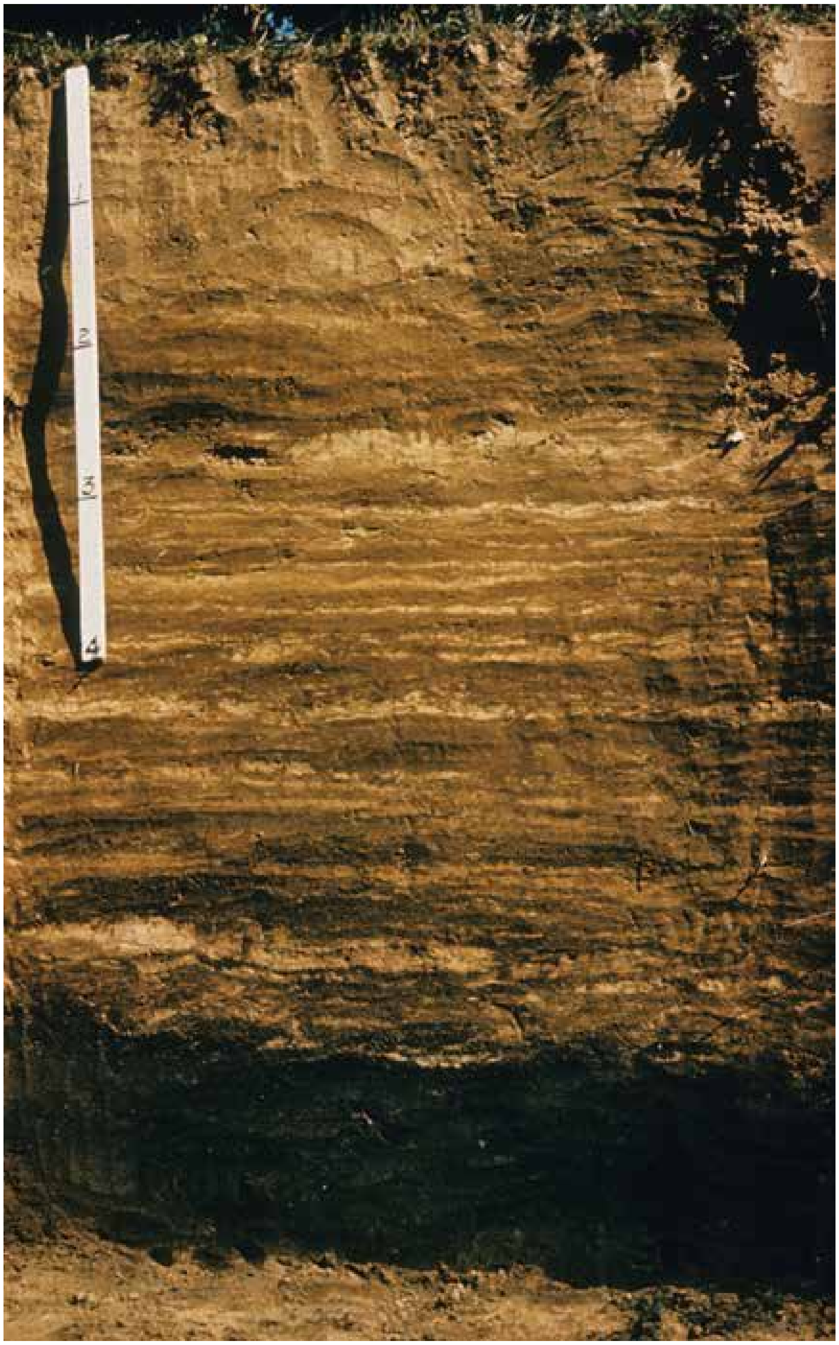
Profile of a shallow Udipsamment in North Carolina. Soil development is minimal and has only progressed to a depth of about 15 to 20 inches. Below this depth is soft, weathered sandstone that has a wavy upper boundary. The sandstone restricts rooting but can be dug fairly easily with hand tools. (Photo courtesy of John Kelley)

Return to Udipsamments

Fluvents Great Groups

Fluvents are mostly brownish to reddish soils that formed in recent water-deposited sediments, mainly on flood plains, fans, and deltas of rivers and small streams but not in backswamps, where drainage is poor. An irregular decrease/increase of carbon content with increasing depth is the basis for the definition of Fluvents. Many Fluvents are frequently flooded unless they are protected by dams or levees. Stratification of the materials is typical. Former surface layers, now covered by more recent sediments, generally have higher contents of organic carbon than layers above or below. Most of the alluvial sediments are derived from eroding upland soils or streambanks and contain an appreciable amount of organic carbon, which is mainly in the clay fraction. Strata of clayey or loamy materials commonly have more organic carbon than the overlying more sandy strata. Thus, the percentage of organic carbon of Holocene age decreases irregularly with increasing depth if the materials are stratified. Because the deposits generally are loamy and recent, however, the percentage of carbon in the deep layers of Fluvents is higher than that in nearby soils that formed in parent materials other than alluvium. In humid regions, the age of the sediments is commonly a few years or decades or a very few hundred years. In arid regions, it may be somewhat greater.





Profile of a Fluvent (specifically a Udifluvent) in China. The soil is comprised of many thin water-deposited strata and has a buried surface layer (black) in the lower part. Scale is in decimeters.

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(Back to Fluvents)

Key to Great Groups of Fluvents (Back to key to suborders)

Fluvents that that have:

1. **Very cold average soil temperature ------------------------------ Gelifluvents**
   These soils have a gelic soil temperature regime.

2. **Cold average soil temperature ------------------------------------ Cryofluvents**
   These soils have a cryic soil temperature regime.

3. **A Mediterranean-type climate ------------------------------------- Xerofluvents**
   These soils have a xeric soil moisture regime (cool and moist in winter and warm and dry in summer).

4. **Somewhat limited soil moisture available for crop growth --- Ustifluvents**
   These soils have an ustic soil moisture regime. Moisture is limited, but available, during portions of the growing season.

5. **Inadequate soil moisture available for crop growth ------- Torrifluvents**
   These soils have an aridic (torric) soil moisture regime.

6. **Seasonally well-distributed precipitation ----------------------- Udifluvents**
   These soils have a udic soil moisture regime.

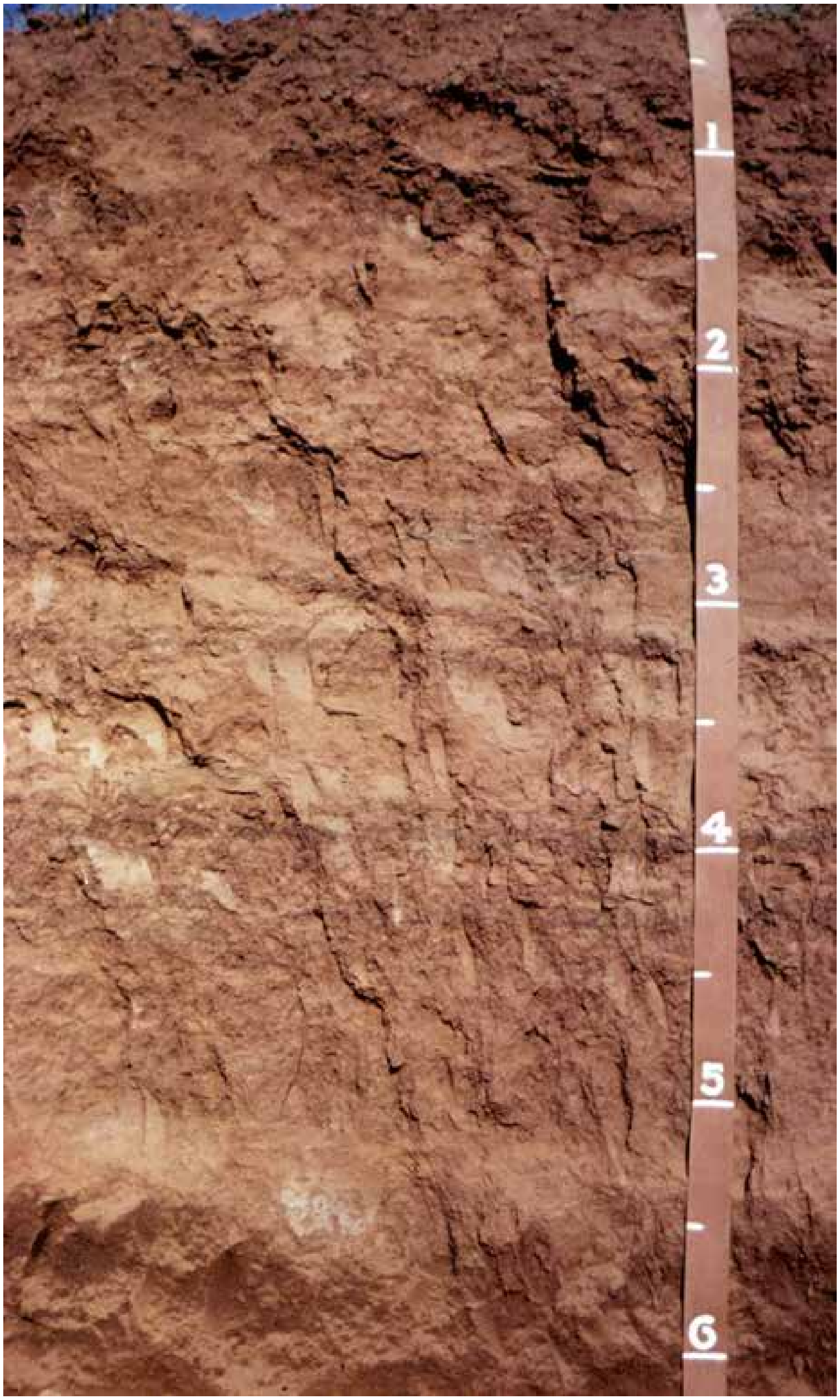
Descriptions of Great Groups of Fluvents

Gelifluvents—These are the Fluvents of very cold regions. They have a gelic soil temperature regime. They tend to have a high content of rock fragments, and some may be shallow to bedrock. They are subject to wide variations in summer high temperatures and winter low temperatures, which result in mean annual soil temperatures of 0 degrees C or less, but without permafrost. In the United States, Gelifluvents occur in Alaska. (Back to Fluvents key)

Cryofluvents—These are the cold Fluvents. The growing season is short and cool. The vegetation typically is a coniferous or mixed forest. In the United States, these soils are mostly in Alaska but some are in mountain valleys in the West. Cryofluvents are moderately extensive. (Back to Fluvents key)

Xerofluvents—These soils have a Mediterranean-type climate (xeric moisture regime) where they are moist in winter and dry in summer. Temperatures range from cool to hot. These soils are on flood plains along rivers or streams or on alluvial fans. Flooding is most common in winter. Some of the soils are flooded in spring because of melting snow in the nearby mountains. The vegetation is commonly mixed forest or grass and shrubs. In the United States, Xerofluvents are mostly in California and the northwestern States. The soils are moderately extensive. (Back to Fluvents key)

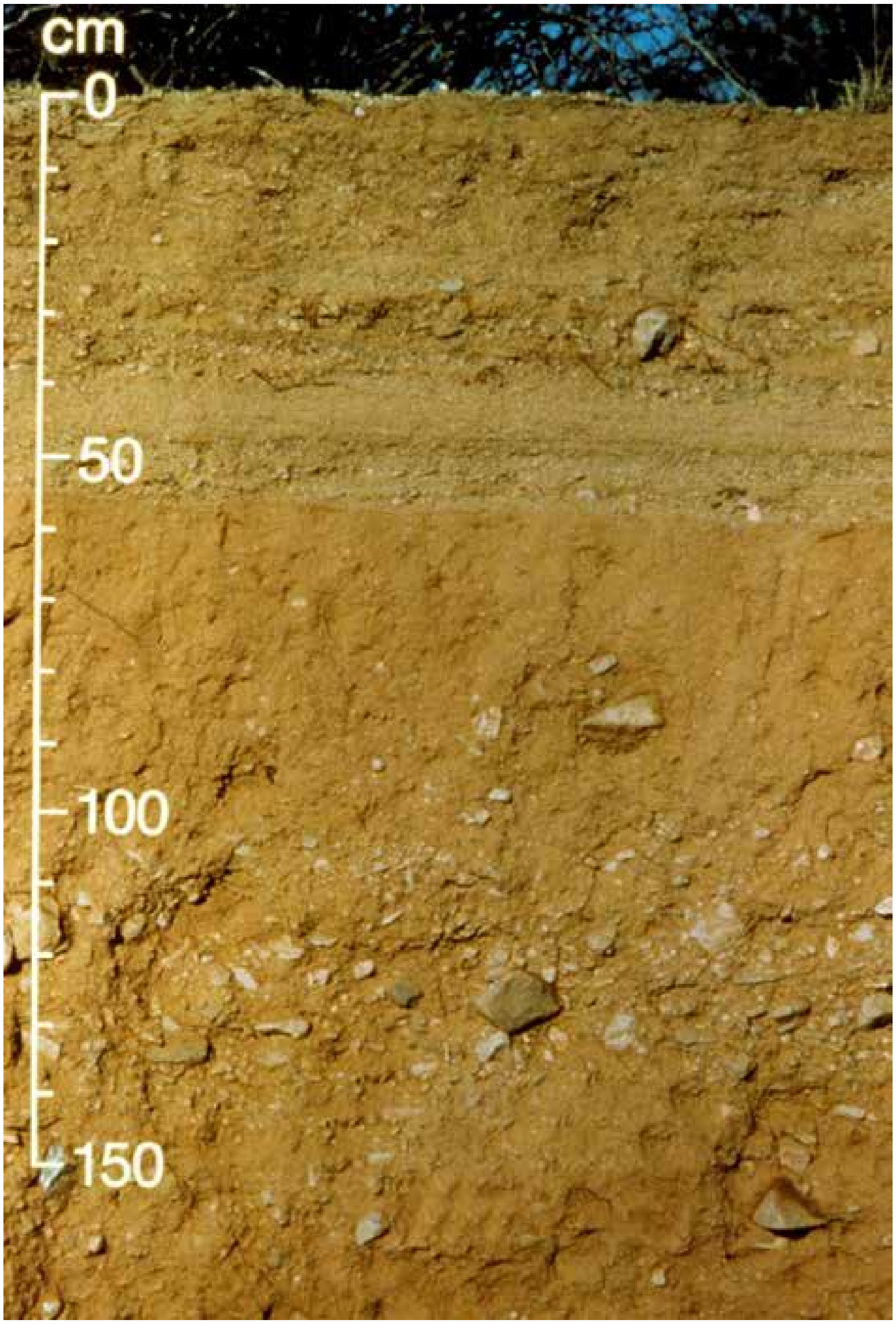
Ustifluvents—These soils have an ustic moisture regime. Although moisture is limited, it is generally available during portions of the growing season. Temperatures range from cool to hot. These soils are on flood plains along rivers and streams in areas of mid or low latitudes. Flooding can occur in any season but is most common in summer in the mid latitudes and during the rainy season in the Tropics. A few of the soils are flooded regularly in summer, even though the summer is rainless, because of melting snow in high mountains. (Back to Fluvents key)



Profile of an Ustifluvent in Texas. The soil consists of relatively thin, loamy layers that were deposited by flooding. Scale is in feet.

Return to Ustifluvents

Torrifluvents—These are the Fluvents of arid climates. They have an aridic (or torric) moisture regime. Temperatures range from cool to hot. Most Torrifluvents have a high pH value and are calcareous, and a few are somewhat salty. They are subject to flooding, but most are not flooded frequently or for long periods. They commonly are irrigated where they occur as larger areas, have a favorable topography, and are close to a source of water. The natural vegetation on Torrifluvents in the United States consisted mostly of grasses, xerophytic shrubs, and cacti. In some parts of the world, however, the only vegetation on these soils has been irrigated crops because the sediments accumulated while the soils were being cultivated. (Back to Fluvents key)



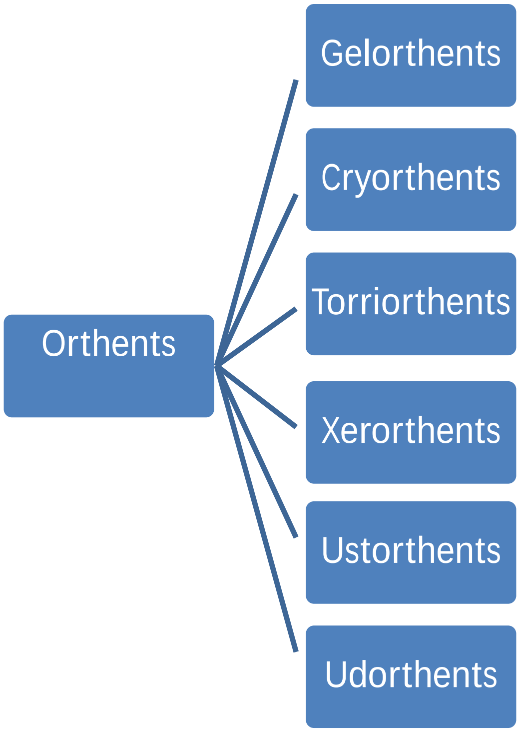
Profile of a Torrifluvent in the southwestern United States. Although in a desert environment, this soil is in a landscape position that receives periodic deposition of material from flooding. This soil has an ochric epipedon about 5 cm thick and no other diagnostic horizons. Note the stratified nature of the profile. The layers with larger rock fragments reflect higher-intensity flooding in the past.

Return to Torrifluvents

Udifluvents—These soils have a udic moisture regime with precipitation distributed throughout the year. Temperatures range from cool to hot. Udifluvents are on flood plains along streams and rivers, and they may be flooded during almost any season. There is little or no evidence of alteration of the fine stratification in the alluvium, although in some Udifluvents, especially those with finer textures, identifying the stratification may be difficult. Some Udifluvents formed under forest vegetation, but many have had no vegetation other than pasture or cultivated crops because the sediments in which the soils formed were deposited while the soils were being used. Udifluvents are extensive in the United States. (Back to Fluvents key)

Orthents Great Groups

Orthents are primarily the Entisols on recent erosional surfaces. The erosion may have been geologic or been human-induced by cultivation, mining, or other activities. Any former soil that was on the landscape before accelerated erosion began has been completely removed or so truncated that the diagnostic horizons for all other soil orders do not occur. A few Orthents are in areas of recent loamy or fine eolian deposits, in areas of solifluction or glacial deposits, or in areas of debris from recent landslides and mudflows. Orthents occur in a wide range of climates and under any vegetation.



Profile of an Orthent (specifically a Udorthent). This soil formed in gravelly, cobbly, and stony colluvium. Other than the ochric epipedon, it has no other diagnostic horizons. Scale is in inches.

(Back to Orthents)

Key to Great Groups of Orthents (Back to key to suborders)

Orthents that have:

1. **Very cold average soil temperature ------------------------------- Gelorthents**
   These soils have a gelic soil temperature regime.

2. **Cold average soil temperature ------------------------------------ Cryorthents**
   These soils have a cryic soil temperature regime.

3. **Inadequate soil moisture available for crop growth ------- Torriorthents**
   These soils have an aridic (torric) soil moisture regime.

4. **A Mediterranean-type climate -------------------------------------- Xerorthents**
   These soils have a xeric soil moisture regime (cool and moist in winter and warm and dry in summer).

5. **Somewhat limited soil moisture available for crop growth --- Ustorthents**
   These soils have an ustic soil moisture regime. Moisture is limited, but available, during portions of the growing season.

6. **Seasonally well-distributed precipitation ----------------------- Udorthents**
   These soils have a udic soil moisture regime.

Descriptions of Great Groups of Orthents

Gelorthents—These are the Orthents of very cold regions. They have a gelic soil temperature regime but lack permafrost within the soil profile. They tend to have a high content of rock fragments, and some may be shallow to bedrock. They are subject to wide variations in summer high temperatures and winter low temperatures, which result in mean annual soil temperatures of 0 degrees C or less, but without permafrost. (Back to Orthents key)

Cryorthents—These are the Orthents of high mountains or high latitudes. Most of them are coarse in texture or are on slopes where depth to bedrock is very shallow or in areas of recent solifluction or volcanic deposits. The vegetation may be coniferous forest, tundra, or the sparse vegetation of very cold, dry areas. Few areas are cultivated. These soils are of small extent in high mountains and in areas of tundra vegetation in the United States. Some of the soils are cold and dry, have a thin efflorescence of salt on the surface during summer, and may be dry in all horizons during some periods. Most of the Cryorthents in the United States still support their native vegetation. (Back to Orthents key)

Torriorthents—These are the dry Orthents of cool to hot, arid regions. They have an aridic (or torric) moisture regime. Generally, they are neutral or calcareous and are on moderate to very steep slopes. A few are on gentle slopes. Many of the gently sloping soils are on rock pediments, are very shallow, have gravelly textures, or are salty. Others are on fans where sediments are recent but have little organic carbon. The vegetation on Torriorthents commonly is sparse and consists mostly of xerophytic shrubs and ephemeral grasses and forbs. The vegetation on a few of the soils is saltgrass. Torriorthents are used mainly for grazing. They are extensive in the western United States. (Back to Orthents key)

Profile of a Torriorthent in the United Arab Emirates. This soil is in a natural drainageway on an alluvial plain that is periodically flooded by runoff after rare but intense rain events in the nearby mountains. This profile is little changed since deposition and exhibits almost no soil development. The upper 60 cm is predominantly windblown deposits. Below this depth, the soil is composed of layers of both windblown and water-deposited sands along with a small amount of gravel. Scale is in cm. (Photo courtesy of Dr. Craig Ditzler)

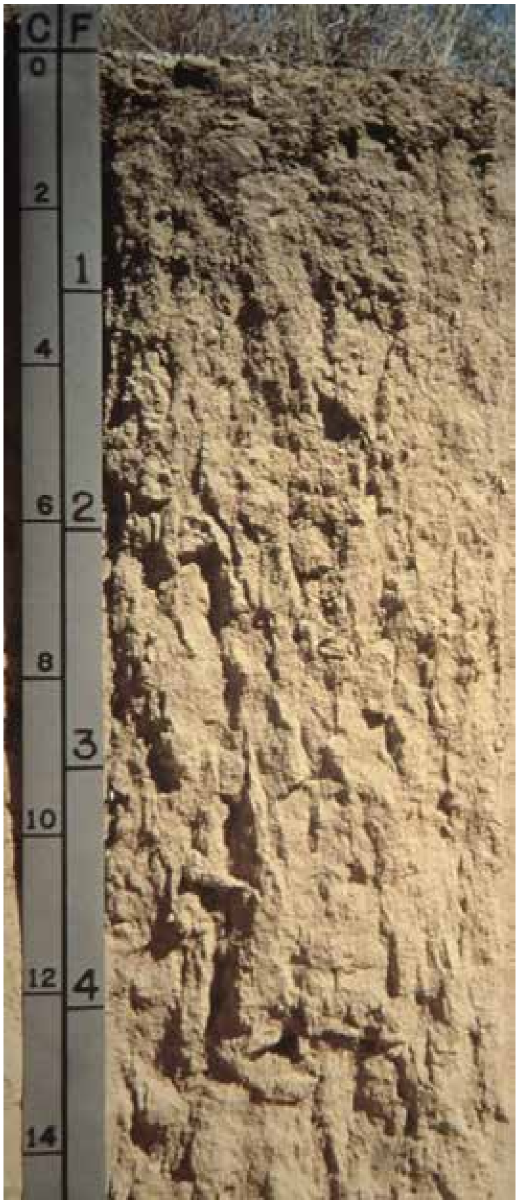
Return to Torriorthents

Xerorthents—These are the Orthents of Mediterranean-type climates (xeric moisture regime) where they are moist in winter and dry in summer. Temperatures range from cool to hot. The soils are generally neutral to moderately alkaline, but some are acid. Slopes are mostly moderate to steep but are gentle in a few areas. Xerorthents commonly are coarse in texture or occur in areas of very recently exposed regolith (such as loess or till), in areas of weakly cemented rocks (such as shale), or in areas of very thin regolith over hard rocks. The vegetation is commonly trees or shrubs, or the soils are used as pasture. (Back to Orthents key)

Profile of a Xerorthent in an area of Turkey with a Mediterranean climate. This clayey soil exhibits little development other than a darkened ochric epipedon about 8 cm thick and some structure in the subsoil. There is little or no development of color or leaching and redistribution of soil constituents within the profile. Scale is in cm.

Return to Xerorthents

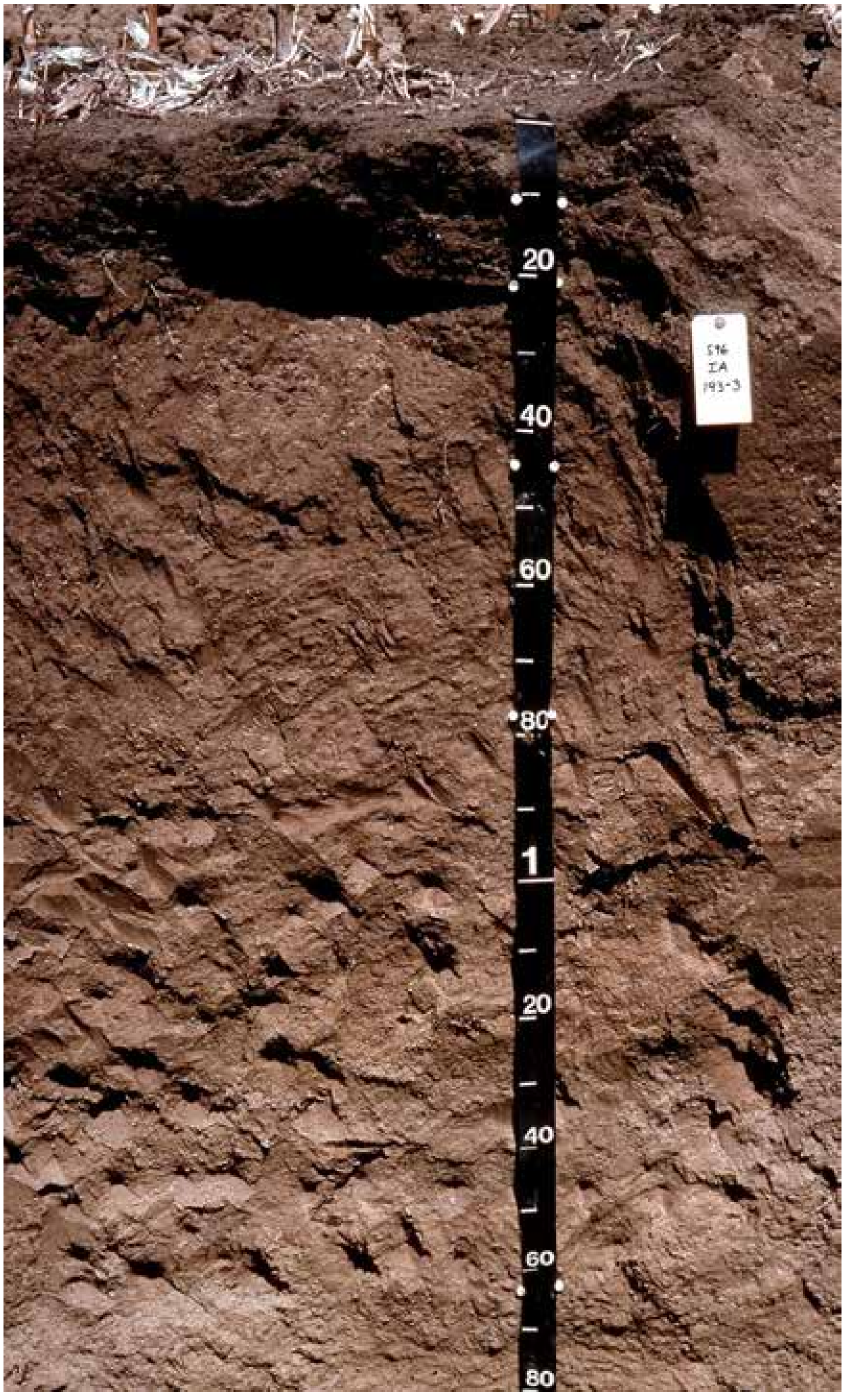
Ustorthents—These are the Orthents of cool to hot regions. They have an ustic moisture regime. Although moisture is limited, it is generally available during portions of the growing season. The soils are generally neutral to calcareous, but some are acid. Slopes are mostly moderate to steep but are gentle in a few areas. Ustorthents commonly occur in areas of very recently exposed regolith, mostly weakly cemented sedimentary deposits, or in areas of thin regolith over hard rocks. The vegetation in warm regions commonly is a deciduous forest or savanna. The soils that have a cooler temperature regime commonly support scattered grasses mixed with xerophytic shrubs. Ustorthents are extensive in the United States, particularly on the Great Plains. (Back to Orthents key)



Profile of an Ustorthent in a semiarid area of the west-central part of the Great Plains. It formed in calcareous windblown silty deposits (loess). This profile has an ochric epipedon about 25 cm thick. The subsoil below this depth has structure but little additional evidence of soil development. For example, there is little color development and calcium carbonate remains fairly evenly distributed throughout the profile (indicating little or no redistribution or removal).

Return to Ustorthents

Udorthents—These are the Orthents that have a udic moisture regime with precipitation distributed throughout the year. Temperatures range from cool to hot. These soils are generally acid to neutral, but some are calcareous. Slopes generally are moderate to steep but are gentle in a few areas. Udorthents commonly occur in areas of very recently exposed regolith (such as loess or till), in areas of weakly cemented rocks (such as shale), or in areas of thin regolith over hard rocks. Many of the gently sloping soils are the result of mining or other earth-moving activities. The vegetation is commonly a deciduous forest, or the soils are used as pasture. Udorthents are extensive on steep slopes in the humid parts of the United States. (Back to Orthents key)



Profile of a Udorthent in Iowa. This soil formed in thick deposits of calcareous loess on side slopes of dissected upland hills. It exhibits little profile development other than an ochric epipedon about 20 cm thick. This soil has free calcium carbonate throughout, which indicates little leaching has occurred. Scale is in cm.

Return to Udorthents

Gelisols Order

Gelisols are very cold soils with permafrost in the subsoil.

General Characteristics

The distinguishing characteristics of Gelisols are very cold soil temperatures and a permanently frozen part (permafrost) within a depth of 200 cm. Periodic freezing and thawing above the permafrost can result in intense frost churning (cryoturbation) which can retard the development of soil horizons in this active zone and may result in irregular or broken horizons, involutions, or organic matter accumulation above the permafrost. Where cryoturbation is less intense, ochric (typically thin and/or light-colored), mollic (rich in humus and bases), umbric (humus-rich with low base saturation), and histic (wet, organic surface layer) epipedons and argillic (clay accumulation), salic (high salts), gypsic (gypsum accumulation), and calcic (calcium carbonate accumulation) subsoil horizons have been observed.

Environment and Processes

The most important environmental factor in the formation of Gelisols is the very cold temperature. Because of the very cold temperature, weathering processes proceed very slowly. Gelisols form in a variety of parent materials, including glacial deposits, mountain colluvium, residuum, and loess, but they also can form in organic materials. Gelisols is the only soil order that includes both organic soils and mineral soils. Cryoturbation is an important dynamic physical process in many Gelisols. Unique “patterned ground” land surface features are characteristic of some areas of Gelisols, especially those with thick permafrost. These features include sorted and unsorted rock circles and stripes, large polygonal surface patterns, ice wedges, frost boils, and pingos.

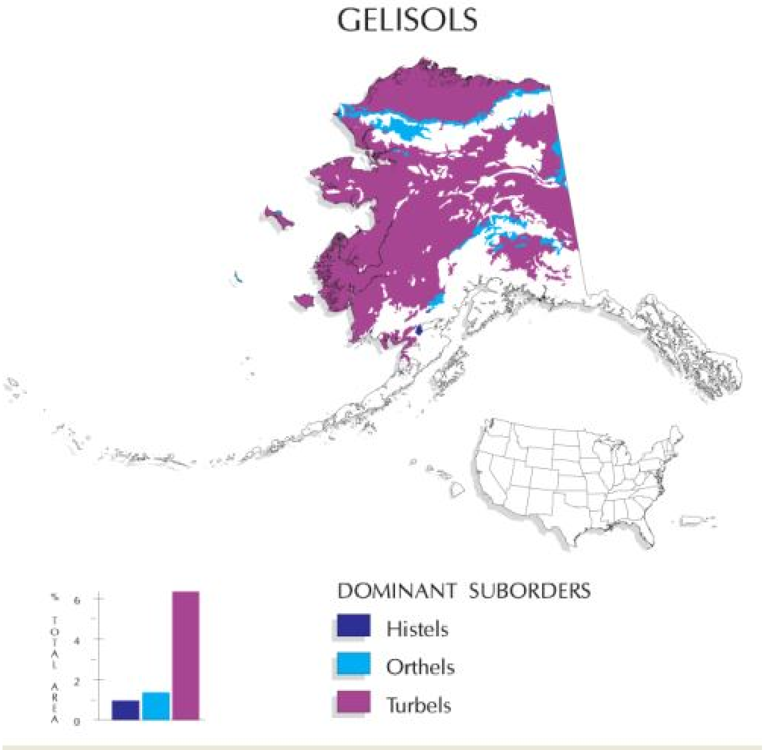
The presence of permafrost presents significant challenges to engineering projects, such as road building and maintenance, housing development, and construction of pipelines. Gelisols are sensitive to disturbance, and problems may result when the permafrost melts and the soils become unstable. An important environmental consequence of the combined very cold temperatures and frost churning has been the accumulation of organic matter within and above the permafrost zone. There is a potential for significant contributions to global warming if the permafrost melts and the organic matter decays, causing the evolution of carbon dioxide and methane.

Location

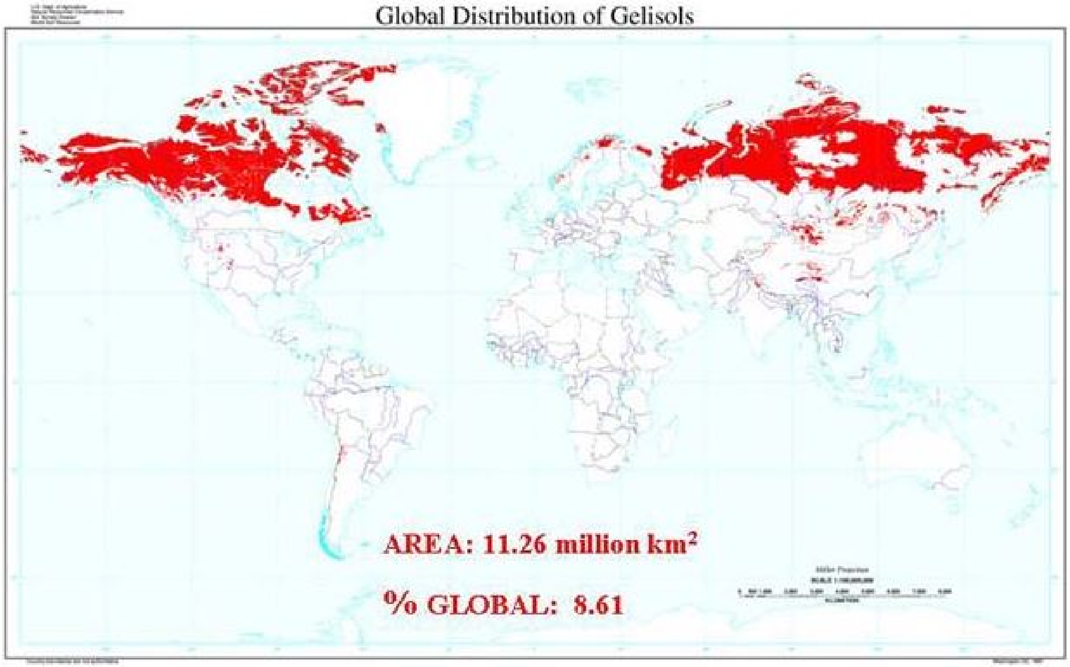
Gelisols are found in tundra, taiga, and boreal forests at high latitudes and occur in both the northern and southern circumpolar regions. While they occur mostly in moist areas, Gelisols have also been recognized in the very dry valleys of Antarctica. They also may occur at very high altitudes in alpine areas on some mountains in the lower latitudes, although these are not known to be extensive. They occur in much of Alaska as well as in Canada, Greenland, Northern Europe, Russia, China, Mongolia, and Antarctica. Globally, Gelisols occupy about 9% of the ice-free land area, but because of the extreme environments in which they are found, they only support about 0.4% of the world's population.

Profile of a Gelisol (specifically an Aquiturbel) in Alaska. Permafrost is at a depth of about 50 cm. Scale is in cm. (Photo courtesy of Dr. David Weindorf)

(Back to Key to Soil Orders)



Gelisols by suborder in the United States.



Global distribution of Gelisols.

Gelisols Suborders

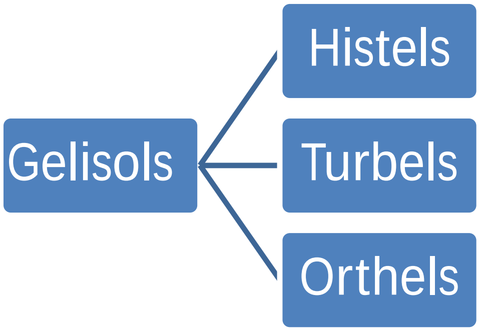
Classification of Gelisols

In the definitions of the suborders, emphasis is divided between significant accumulations of organic matter (Histels), evidence of cryoturbation or frost churning (Turbels), and little evidence of cryoturbation and a lack of significant amounts of organic matter (Orthels).

The great group level reflects a combination of important properties, including the presence of diagnostic horizons, the degree of seasonal saturation, the presence of significant amounts of organic soil material and their degree of decomposition, sandy textures, the presence of massive ice in the soil, and very dry conditions.

The three suborders are:

1. Histels—Gelisols dominated by organic soil materials
2. Turbels—Gelisols with morphology characteristic of cryoturbation
3. Orthels—other simple Gelisols



Key to Suborders of Gelisols

Gelisols that:

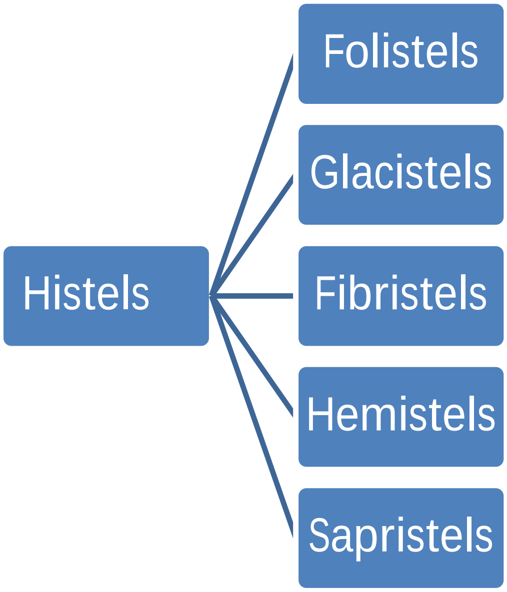
1. **Have organic soil material making up $\geq$ 40 cm (within the upper 50 cm) -- Histels**
   See 12th edition of "Keys to Soil Taxonomy" for specific details regarding required thickness.

2. **Have evidence of cryoturbation (intense frost churning) within the profile -- Turbels**
   Evidence includes irregular, broken, or distorted horizon boundaries; involutions; the accumulation of organic matter on top of the permafrost; ice or sand wedges; and oriented rock fragments.

3. **Have horizons of mineral soil material and are not cryoturbated --- Orthels**

Histels Great Groups

Histels are the Gelisols with large amounts of organic carbon that commonly accumulate under wet, anaerobic conditions. In some cases, Histels are well drained and very coarse textured with organic matter filling voids between rock fragments. Cold temperatures contribute to the accumulation of organic matter.



Profile of a Histel (specifically a Fibristel) in Alaska. The organic soil material (brown and black) ranges from about 20 to 40 cm in thickness and is intermingled with the underlying mineral soil material by cryoturbation. Permafrost is at a depth of about 40 cm. Scale is in decimeters.

(Back to Histels)

Key to Great Groups of Histels (Back to key to suborders)

Histels that:

1. **Are freely drained -- Folistels**
   These soils are saturated < 30 days (cumulative) each year and are not artificially drained.

2. **Have a glacic layer (≥ 75% ice) within a depth of 100 cm ---- Glacistels**
   These soils have < 75% sphagnum fibers in the upper 50 cm. The ice layer is ≥ 30 cm thick.

3. **Are predominantly composed of fibric (slightly decomposed) soil material to a depth of 50 cm or more -------------------------------- Fibristels**

4. **Are predominantly composed of hemic (moderately decomposed) soil material to a depth of 50 cm or more -------------------------- Hemistels**

5. **Are predominantly composed of sapric (highly decomposed) soil material to a depth of 50 cm or more ------------------------------ Sapristels**

Descriptions of Great Groups of Histels

Folistels—These are the more or less freely drained Histels that consist primarily of organic layers (O horizons) derived from plant litter resting directly on rock, or they formed on very coarse materials that consist of gravel or larger rock fragments in which the voids are mostly filled with organic materials. Plant roots grow in the organic materials. These soils are rare in the world. (Back to Histels key)

Glacistels—These are the wet Histels that have 30 cm or more of ice within a depth of 100 cm. They are saturated with water for ≥ 30 total days each year. Disturbance of the surface-insulating layer causes the ice layer to melt and the soils to collapse. Glacistels occur in Alaska, Canada, and Siberia. (Back to Histels key)

Profile of a Glacistel in Alaska. This soil consists of organic material (black surface layer) underlain by a thick layer of ice (glacic horizon). Although some organic and mineral soil material is incorporated within the ice (note the dark stains, especially in the upper part of the ice), the glacic horizon consists mostly of water.

Return to Glacistels

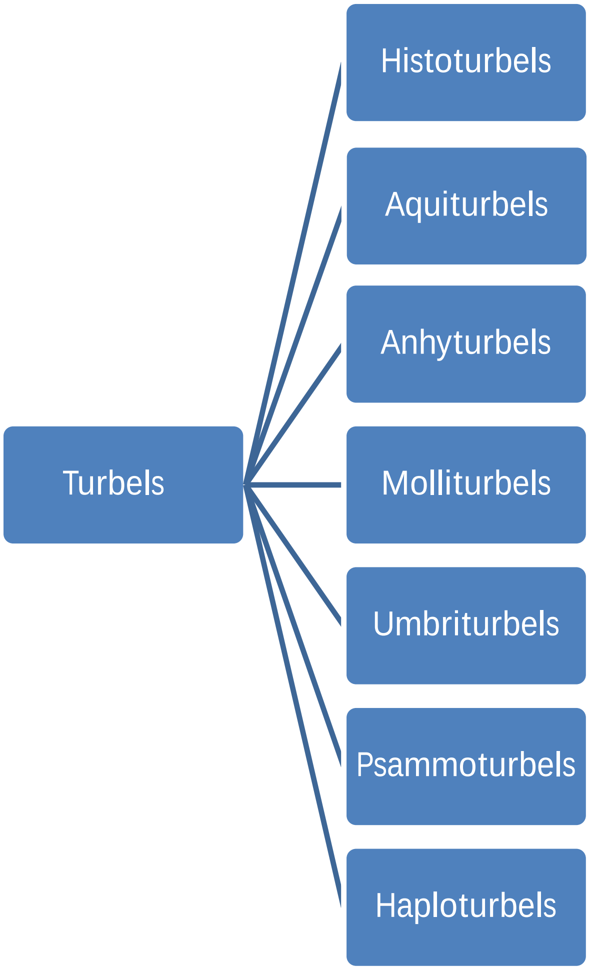
Fibristels—These are the wet Histels in which the organic materials are slightly decomposed. Most of the fiber is not destroyed by rubbing between the thumb and fingers. The botanical origin of much of the material can be readily determined. Many of these soils have ground water near the surface nearly all the time. Fibristels occur in depressional or level areas, commonly adjacent to water bodies. They are of small extent and occur in Alaska, Canada, and Siberia. (Back to Histels key)

Hemistels—These are the wet Histels in which the organic materials are moderately decomposed. The botanical origin of the organic material can only be determined for some of the material. The fiber content is about one-sixth to two-thirds after rubbing between the thumb and fingers. Water is at or very close to the surface of these soils much of the time, unless artificial drainage is provided. The level of ground water may fluctuate but seldom drops much below the surface. Hemistels occur in depressional areas or adjacent to water bodies. These soils are known to occur in Siberia, Canada, and Alaska. (Back to Histels key)

Sapristels—These are the wet Histels in which the organic materials are well decomposed. The botanical origin of the organic material is difficult to determine. The fiber content of most of the organic material is less than one-sixth after rubbing between the thumb and fingers. Sapristels occur in areas where ground water tables tend to fluctuate within the soil or where the soil was better aerated during drier periods in the past, which led to increased organic matter decomposition. (Back to Histels key)

Turbels Great Groups

Turbels are the Gelisols that have one or more horizons with evidence of cryoturbation (intense frost churning) in the form of irregular, broken, or distorted horizon boundaries; involutions; the accumulation of organic matter on top of the permafrost; ice or sand wedges; or oriented rock fragments. Cryoturbation occurs only in soils that have sufficient moisture for the formation of ice crystals. Soils that have cryoturbated horizons and are dry for most of the year were probably moister in the past. Turbels are the dominant suborder of Gelisols. They account for about half of the Gelisols worldwide. These soils are common in the High and Middle Arctic Vegetation Regions of North America and Eurasia, at latitudes of 65 degrees north or more.



Profile of a Turbel (specifically a Haploturbel) in Alaska. Involutions of soil material (brown) are mixed into the underlying soil by cryoturbation.

(Back to Turbels)

Key to Great Groups of Turbels (Back to key to suborders)

Turbels that have:

1. **More than 40% organic soil materials in the upper 50 cm -- Histoturbels**
   Organic soil materials are in ≥ 30% of the pedon. Histoturbels cannot have a folistic epipedon (freely drained, organic surface layer).

2. **A seasonal high water table within a depth of 50 cm ------- Aquiturbels**
   Redoximorphic features (gray and red color patterns) are evidence of a seasonal high water table. Artificially drained sites are included in Aquiturbels. See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding color of redoximorphic features.

3. **Very dry soil moisture conditions (anhydrous conditions) --- Anhyturbels**
   Water is held at ≥ 1500 kPa tension for much of the time when soil temperature is > 0 ºC. See 12th edition of "Keys to Soil Taxonomy" for specific criteria for anhydrous conditions.

4. **A mollic (rich in humus and bases) epipedon ----------------- Molliturbels**

5. **An umbric (humus-rich with low base saturation) epipedon --- Umbriturbels**

6. **Sandy texture throughout the upper 100 cm ------------- Psammoturbels**
   Psammoturbels have < 35% rock fragments. Required depth of sandy textures is less in profiles with bedrock above a depth of 100 cm.

7. **An ochric (typically thin and/or light-colored) epipedon and a cryoturbated subsoil -- Haploturbels**

Descriptions of Great Groups of Turbels

Histoturbels—These soils have organic soil materials making up much, or all, of the surface soil to a depth of 50 cm or more. Commonly, the organic materials are thicker in the micro-low positions on the landscape and thinner in the micro-high positions. These soils are commonly saturated at or near the surface for some time during most years. They commonly have redoximorphic features (gray and red color patterns). (Back to Turbels key)

Aquiturbels—These soils are saturated with water close to the surface. Saturation commonly occurs in spring, when water perches on the permafrost and temperatures are warm enough for oxygen depletion and iron reduction. These soils can have mollic (rich in humus and bases), umbric (humus-rich with low base saturation), or ochric (typically thin and/or light-colored) epipedons. They occur in depressional areas in Alaska, Canada, and Eurasia. (Back to Turbels key)

Profile of an Aquiturbel in Alaska. The permafrost begins at a depth of about 50 cm. Active freezing and thawing cycles take place above the permafrost. This profile exhibits evidence of cryoturbation (mixing by frost action), such as thin ice lenses and pockets of darker colored organic matter mixed into the lighter colored surrounding soil material. Frost heaving results in a hummocky surface. Note that the center of the photo (with tape) is a micro-high and the left and right sides are micro-lows. This pattern is repeated across the hummocky landscape. Scale is in cm.

Return to Aquiturbels

Anhyturbels—These soils have anhydrous conditions (very dry) and may have dry permafrost (i.e., insufficient moisture for interstitial ice). The cold deserts where Anhyturbels occur commonly receive less than 30 mm of precipitation annually. These soils support little or no vegetation. Anhyturbels are limited in extent but occur in continental Antarctica, northern Greenland, and the cold, dry mountains of Eurasia at elevations of more than 3,700 meters. These soils have experienced climatic periods in the past when more moisture was available. (Back to Turbels key)

Molliturbels—These soils have a mollic (rich in humus and bases) epipedon. They are known to occur in Alaska, Canada, and Siberia. On the North Slope of the Brooks Range in Alaska, they support vegetation that differs from that on the more acid Umbriturbels. (Back to Turbels key)

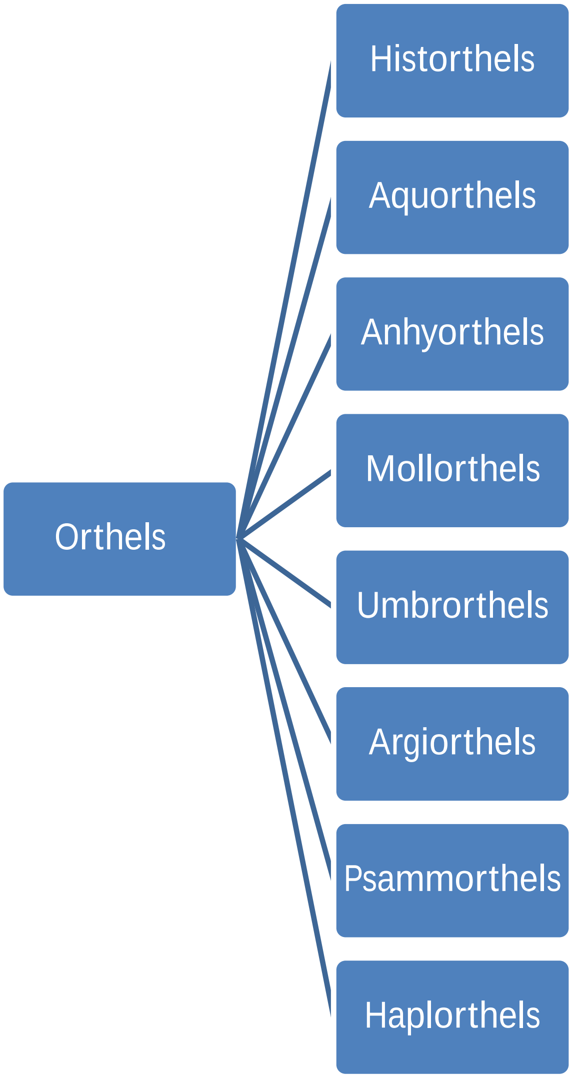
Umbriturbels—These soils have an umbric (humus-rich with low base saturation) epipedon. Umbriturbels are known to occur in Alaska, Canada, Greenland, and Siberia. On the North Slope of the Brooks Range in Alaska, they support vegetation that differs from that on Molliturbels. (Back to Turbels key)

Psammoturbels—These soils have less than 35% (by volume) rock fragments and a texture of loamy fine sand or coarser in all layers to a depth of 100 cm, or to a root-limiting layer. They commonly have an ochric (typically thin and/or light-colored) epipedon. (Back to Turbels key)

Haploturbels—These soils have an ochric (typically thin and/or light-colored) epipedon and have sufficient moisture for cryoturbation. Commonly, the cryoturbation is not well expressed. These soils occur in Alaska, Canada, and Siberia. (Back to Turbels key)

Orthels Great Groups

Orthels are the Gelisols that show little or no evidence of cryoturbation (intense frost churning) and are the second most abundant suborder of Gelisols. These soils occur primarily within the zone of widespread permafrost or in areas of coarse textured materials in the continuous zone of permafrost. Orthels are generally drier than Turbels and Histels. They occur in the southern Andes and the high latitudes of the Northern Hemisphere.



Key to Great Groups of Orthels (Back to key to suborders)

Orthels that have:

1. **A histic epipedon (wet, organic surface layer) ---------------- Historthels**

2. **A seasonal high water table within a depth of 50 cm -------- Aquorthels**
   Redoximorphic features (gray and red color patterns) are evidence of a seasonal high water table. Artificially drained sites are included in Aquiturbels. See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding color of redoximorphic features.

3. **Very dry soil moisture conditions (anhydrous conditions) -- Anhyorthels**
   Water is held at ≥ 1500 kPa tension for much of the time when soil temperature is > 0 °C. See 12th edition of "Keys to Soil Taxonomy" for specific criteria for anhydrous conditions.

4. **A mollic (rich in humus and bases) epipedon ----------------- Mollorthels**

5. **An umbric (humus-rich with low base saturation) epipedon --- Umbrorthels**

6. **An argillic (clay accumulation) subsoil horizon within a depth of 100 cm -- Argiorthels**

7. **Sandy texture between depths of 25 and 100 cm -------- Psammorthels**
   Psammorthels have < 35% rock fragments. Required depth of sandy textures is less in profiles with bedrock above a depth of 100 cm.

8. **An ochric (typically thin and/or light-colored) epipedon and a cambic (minimal soil development) subsoil horizon ------------------ Haplorthels**
   Some Haplorthels do not have a cambic horizon.

Descriptions of Great Groups of Orthels

Historthels—These soils have organic materials at the surface. Commonly, the organic materials are thicker in the micro-low positions on the landscape and thinner in the micro-high positions. These soils are commonly saturated at or near the surface for some time during most years and have redoximorphic features (gray and red color patterns). (Back to Orthels key)

Aquorthels—These soils are saturated and depleted of oxygen (reduced) close to the surface for at least part of the year. They have redoximorphic depletions (gray areas with loss of iron/manganese oxides and/or clay) with chroma of 2 or less. These soils are common in the center of large-scale, low-centered polygons of patterned ground along the North Slope of the Brooks Range in Alaska. (Back to Orthels key)

Anhyorthels—These soils have anhydrous conditions (very dry). They commonly have dry permafrost (i.e., insufficient moisture for interstitial ice). The cold deserts where Anhyorthels are found commonly receive less than 30 mm of precipitation annually. These soils support little or no vegetation. They are limited in extent but are known to occur in continental Antarctica, the High Arctic (northern Greenland and Ellesmere Island), and the cold, dry mountains of Eurasia at elevations of more than 3,700 meters. (Back to Orthels key)

Mollorthels—These soils have a mollic (rich in humus and bases) epipedon. They are more or less well drained or moderately well drained. They are known to occur in Alaska, Canada, and Siberia. On the North Slope of the Brooks Range in Alaska, they support vegetation that differs from that on the more acid Umbrorthels. (Back to Orthels key)

Umbrorthels—These soils have an umbric (humus-rich with low base saturation) epipedon. They are more or less well drained or moderately well drained. They are known to occur in Alaska, Canada, and Siberia. On the North Slope of the Brooks Range in Alaska, they support vegetation that differs from that on Mollorthels. (Back to Orthels key)

Argiorthels—These soils have an argillic (clay accumulation) subsoil horizon. They are typically well drained or moderately well drained. The argillic horizon in these soils commonly is weakly expressed. Argiothels are rare in the world but are known to occur in northern Siberia. (Back to Orthels key)

Psammorthels—These soils have less than 35% (by volume) rock fragments and a texture of loamy fine sand or coarser in all layers between depths of 25 and 100 cm, or to a root-limiting layer. They are more or less well drained or moderately well drained. These soils commonly have an ochric (typically thin and/or light-colored) epipedon. (Back to Orthels key)

Haplorthels—These soils have an ochric (typically thin and/or light-colored) epipedon and commonly a cambic (minimal soil development) subsoil horizon but have insufficient moisture prior to freezing for cryoturbation. They are typically well drained or moderately well drained. They occur in Alaska, Canada, and Siberia. (Back to Orthels key)

Histosols Order

Histosols are soils that formed in decaying organic material.

General Characteristics

Histosols formed in thick accumulations of organic matter from decaying plant material. The organic-dominated layers are typically at least 40 cm thick and commonly much thicker. They have a minimum of 12 to 18% organic carbon, by weight (depending on clay content), and most have significantly more than this. Histosols do not exhibit the kinds of horizons common to mineral soils but rather have layers, or tiers, that vary in color, botanical origin of the organic material, amount of mixed-in mineral soil material, degree of decomposition, and other properties. Histosols generally have significantly lower bulk density and higher nutrient- and water-holding capacities than most mineral soils.

Environment and Processes

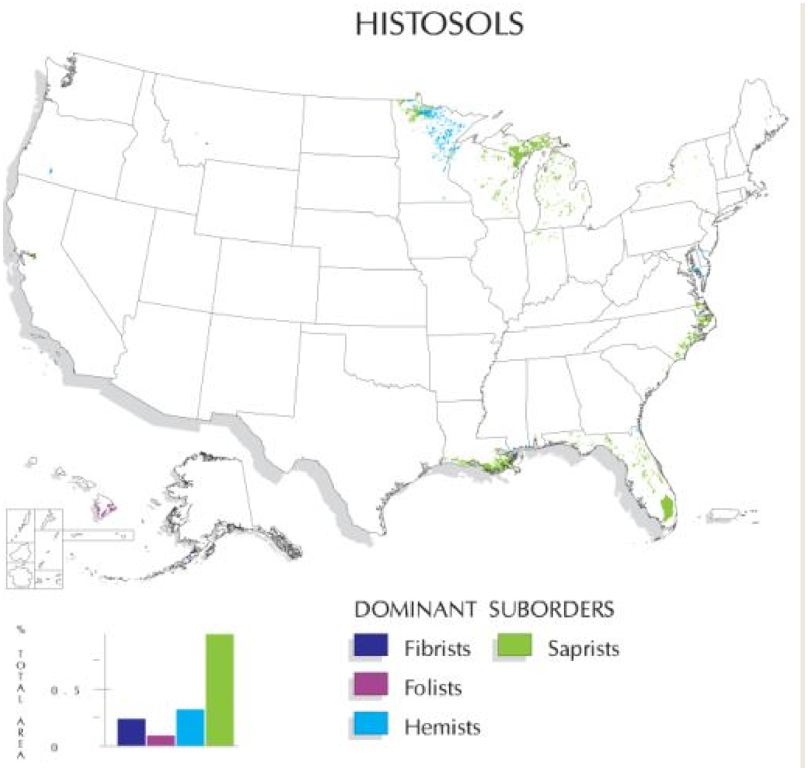
Histosols occur at all latitudes, ranging from the tropics to temperate areas and extending to the boreal forests of high latitudes. They form in environments where inputs of organic matter exceed losses due to decomposition. These conditions are generally in cool, wet environments where precipitation exceeds evaporation. Histosols are common in low-lying areas with water-logging and anaerobic (oxygen-depleted) conditions. Some are on hillsides where local ground-water seeps are prevalent. However, some Histosols are more or less well drained and formed in cool upland positions. These Histosols are characterized by organic soil layers over shallow bedrock, or they are very gravelly to extremely bouldery and have organic soil material filling the voids between rock fragments. Histosols also occur in permanently submerged areas as subaqueous soils. The general properties of the Histosols in a given area are reflective of the general types of plants that supplied the organic matter (for example, peat, sedges, rushes, or woody plants), pH, activity of microbes, and the hydrology of the area. In general, Histosols in areas of ground-water discharge tend to have a higher nutrient status than those in areas of ground-water recharge.

Location

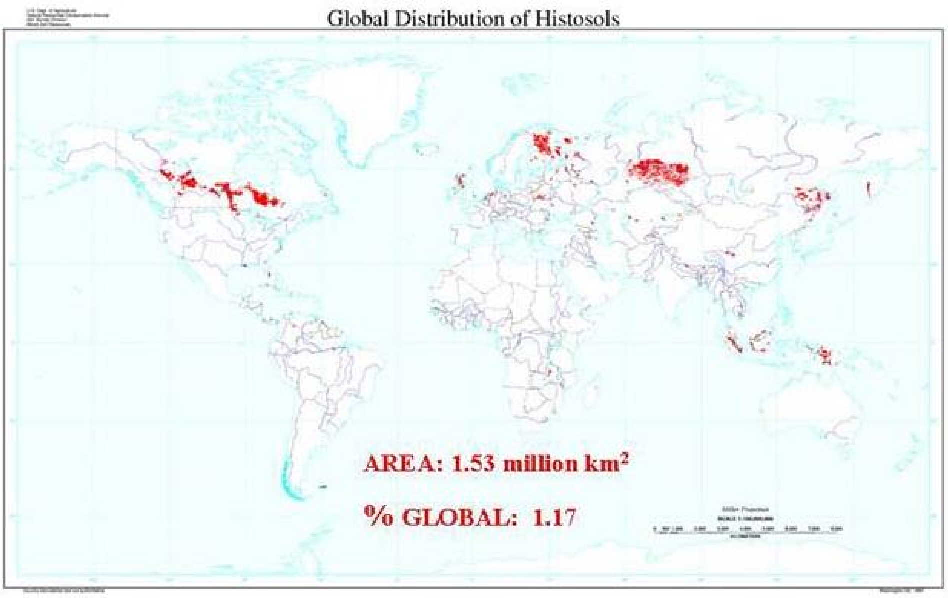
Globally, Histosols occupy about 1% of the ice-free land area. They are particularly extensive in the northern boreal areas of North America, Northern Europe, and Russia. In the United States, Histosols are fairly extensive in Alaska, along the southeast coast, and in the north-central States. They can be found in many locations where cool, wet conditions promote the accumulation of organic soil deposits.

Profile of a Histosol.

(Back to Key to Soil Orders)



Histosols by suborder in the United States. Note: This map was produced before the introduction of the Wassists suborder. Wassists are predominantly in shallow-water coastal bays and estuaries and may also occur in some inland freshwater areas.



Global distribution of Histosols.

Histosols Suborders

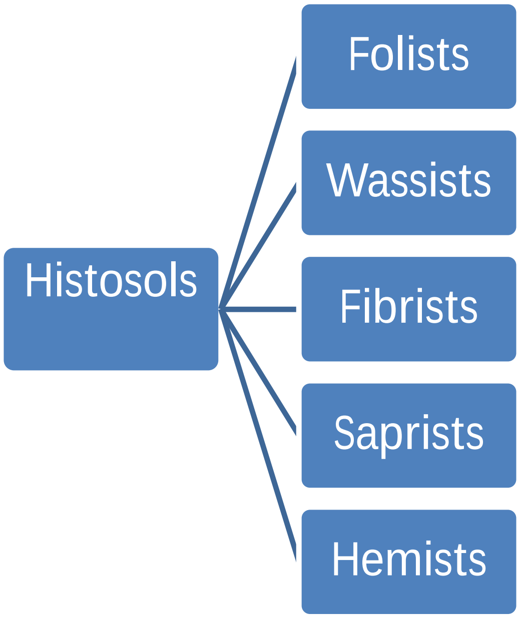
Classification of Histosols

In the definitions of the suborders, emphasis is placed on drainage (Folists), permanent submergence (Wassists), and the general level of organic matter decomposition (Fibrists, Hemists, and Saprists).

The great group level reflects a combination of important properties, including cold soil temperature; soil moisture regimes (in the Folists); the presence of a sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon or sulfidic materials (acid-producing, oxidizable sulfur compounds) as well as the presence of humilluvic material (illuviated humus); and the dominance of *Sphagnum* (with its unique water-holding capacity) as the botanical source of the organic material. In addition, the great groups of the Wassists are separated based on inundation by fresh, brackish, or salty water.

The five suborders are:

1. Folists—freely drained Histosols (saturated less than 30 days)
2. Wassists—permanently submerged Histosols
3. Fibrists—wet Histosols exhibiting the least decomposition
4. Saprists—wet Histosols exhibiting the most decomposition
5. Hemists—wet Histosols exhibiting intermediate decomposition



Key to Suborders of Histosols

Histosols that are:

1. **Freely drained -- Folists**
   These soils are saturated < 30 days (cumulative) each year and are not artificially drained.

2. **Continuously and permanently inundated by water ------------ Wassists**
   Wassists include soils in tidal areas that are exposed to the atmosphere < 3 hours each day. Water is shallow enough (≤ 2.5 m) to permit rooted, often submerged vegetation to grow.

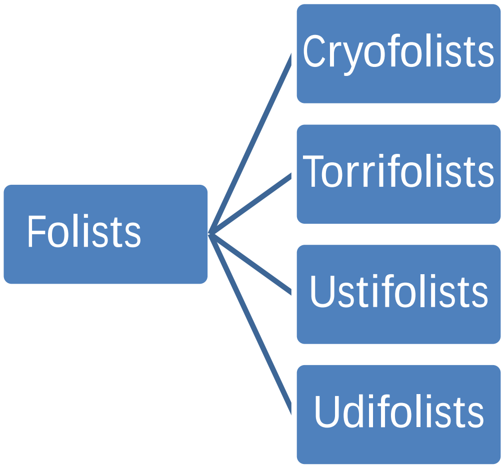
3. **Predominantly (> 50%) composed of fibric (slightly decomposed) soil material between depths of 30 and 90 cm ---------------------------- Fibrists**
   If a mineral soil layer ≥ 40 cm thick begins within a depth of 90 cm, then fibric soil material must be dominant from the soil surface to the top of the mineral layer. Fibrists do not have a sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon within a depth of 50 cm or sulfidic materials (acid-producing, oxidizable sulfur compounds) within a depth of 100 cm.

4. **Predominantly (> 50%) composed of sapric (highly decomposed) soil material between depths of 30 and 90 cm -------------------------- Saprists**
   If a mineral soil layer ≥ 40 cm thick begins within a depth of 90 cm, then sapric soil material must be dominant from the soil surface to the top of the mineral layer.

5. **Predominantly (> 50%) composed of hemic (moderately decomposed) soil material between depths of 30 and 90 cm --------------------- Hemists**
   If a mineral soil layer ≥ 40 cm thick begins within a depth of 90 cm, then hemic soil material must be dominant from the soil surface to the top of the mineral layer.

Folists Great Groups

Folists are the more or less freely drained Histosols that consist primarily of O horizons derived from leaf litter, twigs, and branches resting on rock or on fragmental materials (gravel, cobbles, stones, and boulders) in which the interstices are filled or partly filled with organic materials. Plant roots grow only in the organic materials. Many of these soils are in very humid climates, ranging from the Tropics to high latitudes and high elevations, but some are semiarid or arid areas. Most of the Folists in the United States are in Hawaii and Alaska. There are some Folists in the mountains in the western part of the United States, in the northern Lake States, and in the northeastern part of the United States.



Key to Great Groups of Folists (Back to key to suborders)

Folists that have:

1. **Cold average soil temperature -------------------------------------- Cryofolists**
   These soils have a cryic soil temperature regime.

2. **Inadequate soil moisture available for crop growth ---------- Torrifolists**
   These soils have an aridic (or torric) soil moisture regime.

3. **Somewhat limited soil moisture available for crop growth -- Ustifolists**
   These soils have either an ustic or xeric soil moisture regime.

4. **Seasonally well-distributed precipitation ------------------------- Udifolists**
   These soils have a udic soil moisture regime.

Descriptions of Great Groups of Folists

Cryofolists—These are the cold Folists. In the United States, they occur mostly in southeastern Alaska, where the climate is cool, oceanic, and very humid. They are on gentle to very steep slopes. Their vegetation is primarily coniferous forests, and the only part of the soils in which there are plant roots is the O horizon. Beneath the O horizon, there may be a few centimeters of mineral soil material, or bedrock, or there may be fragmental materials in which the interstices are filled or partly filled with organic materials. (Back to Folists key)

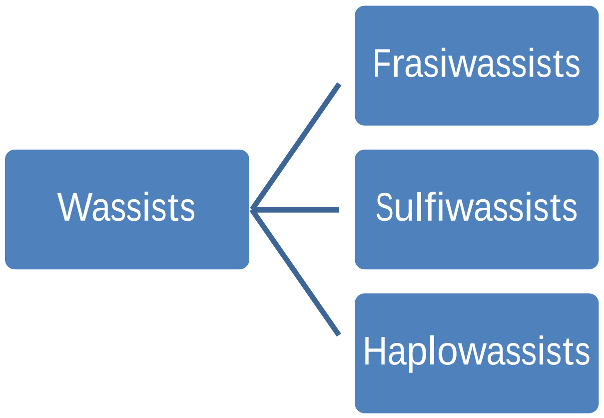
Torrifolists—These are the Folists of arid regions. They occur in Hawaii, chiefly on lava flows in areas that receive little rainfall. The vegetation is mostly fountaingrass mixed with shrubs. (Back to Folists key)

Ustifolists—These are the Folists with somewhat limited soil moisture available for plant growth. They have either an ustic moisture regime (moisture is limited, but available, during periods of plant growth) or a xeric moisture regime (cool and moist in winter and warm and dry in summer). These soils have an O horizon that overlies, or is in, fragmental materials or that directly overlies bedrock that is less than 50 cm from the surface. (Back to Folists key)

Udifolists—These are the Folists in humid areas with seasonally well-distributed precipitation. They have a udic (or perudic) soil moisture regime. They occur in Hawaii, chiefly on lava flows in areas that receive very high amounts of well-distributed rainfall. The vegetation is mostly forest mixed with tree ferns. (Back to Folists key)

Wassists Great Groups

Wassists are the Histosols with a subaqueous drainage class. They formed in shallow, permanently submerged environments and have a positive water pressure at the soil surface for more than 21 hours each day in all years. The 21-hour minimum allows for short daily exposure of the soil surface in areas with large tidal fluctuations, such as the coastal areas of eastern Maine in the United States. Some Wassists formed in saltwater environments, while others formed in freshwater lakes and ponds with low salinity. Most Wassists are known to occur in Holocene-age depositional environments. The organic materials are derived from wood, grasses, sedges, submerged aquatic vegetation, or any combination of these materials. Wassists are known to occur in any climate warmer than cryic. These soils are important for wildlife habitat.



Key to Great Groups of Wassists (Back to key to suborders)

Wassists that have:

1. **Little or no salinity --- Frasiwassists**
   To a depth of 100 cm, electrical conductivity is < 0.2 dS/m (measured in a 5:1, by volume, mixture of water and soil).

2. **Sulfidic materials (acid-producing, oxidizable sulfur compounds) within a depth of 50 cm -- Sulfiwassists**
   The layer containing sulfidic materials is ≥ 15 cm thick.

3. **Significant salinity levels --- Haplowassists**
   To a depth of 100 cm, electrical conductivity is ≥ 0.2 dS/m (measured in a 5:1, by volume, mixture of water and soil).

Descriptions of Great Groups of Wassists

Frasiwassists—These are the Wassists that formed in fresh water. They have a low electrical conductivity (< 0.2 dS/m) in a 1:5 (by volume) soil:water ratio throughout the upper meter. These soils are derived from freshwater organic and loamy materials and occur in natural and man-made water bodies. Many of these soils have high levels of nutrients that support a large number of native and non-native vegetation. They are believed to be of large extent in the United States and are most extensive in mid to northern latitudes. (Back to Wassists key)

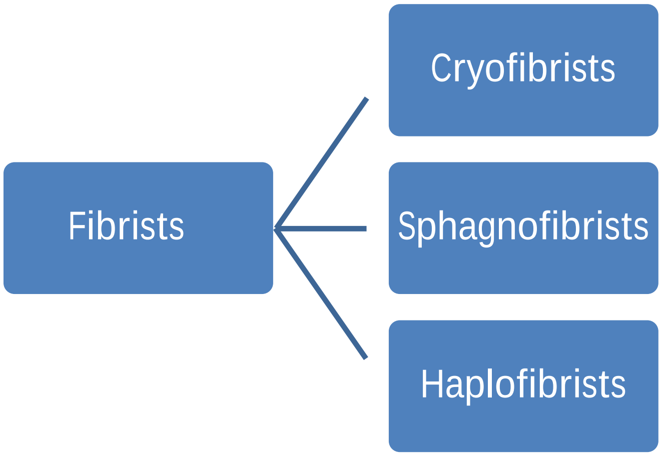
Sulfiwassists—These are the Wassists that formed in salt or brackish water and have horizons with sulfidic materials totaling 15 cm or more within the upper 50 cm. They are potentially extremely acid or ultra acid. These soils are of small extent in the United States and occur mainly along the Atlantic and Gulf coasts. (Back to Wassists key)

Haplowassists—These are the Wassists that formed in salt or brackish water and that do not have a thick layer of sulfidic materials near the surface. They are of small extent in the United States, occurring mainly along the Atlantic and Gulf coasts. (Back to Wassists key)

Fibrists Great Groups

Fibrists are the wet Histosols in which the organic materials are only slightly decomposed. A significant amount of the soil consists of fibers that remain after rubbing between the thumb and fingers. The botanic origin of the materials can be readily determined. The bulk density is commonly less than 0.1 g/cm^3. Many Fibrists have ground water near the soil surface nearly all the time. A few areas of Fibrists are artificially drained. The level of the ground water fluctuates but seldom drops much below about 30 cm.

Fibrists are of relatively small extent but occur from the Equator to the high latitudes. They are in closed depressions and in broad flat areas, such as coastal plains. Most are under natural vegetation.



Key to Great Groups of Fibrists (Back to key to suborders)

Fibrists that have:

1. **Cold average soil temperature -------------------------------------- Cryofibrists**
   These soils have a cryic soil temperature regime.

2. ***Sphagnum* composing ≥ 3/4 of the volume to a depth of 90 cm --- Sphagnofibrists**
   See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding depth of Sphagnum*-dominated material.*

3. **Vegetation of which more than 1/4 of the volume is something other than *Sphagnum* --- Haplofibrists**
   Vegetation includes wood, grasses, sedges, mosses, and other herbaceous plants or some combination of these.

Descriptions of Great Groups of Fibrists

Cryofibrists—These are the cold Fibrists. The fibers may be derived from any plant, woody or herbaceous. These soils may freeze during the winter, or they may have a climate in which they do not freeze during winter in most years but are cold in summer. In either situation, the low temperatures limit the use of the soils. Most of these soils support native vegetation. (Back to Fibrists key)

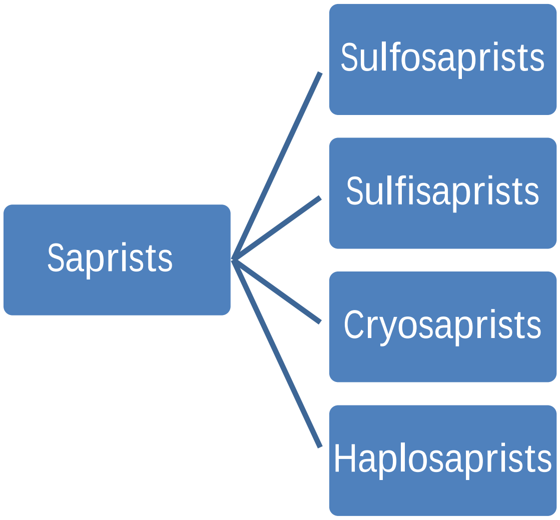
Sphagnofibrists—These Fibrists are derived mainly from the various species of *Sphagnum* and associated herbaceous plants. At least three-fourths of the fibers, by volume, are *Sphagnum* in at least the upper 90 cm of the soil or throughout the soil if there is a root-limiting layer within a depth of 90 cm. Most of these soils have cool temperatures. The structure of *Sphagnum*, with its water-holding cells, makes these soils unique. For this reason, these soils are called Sphagnofibrists. (Back to Fibrists key)

Haplofibrists—These are the Fibrists in which more than one-fourth of the fiber volume is derived from wood, grasses, sedges, mosses, and other herbaceous plants or from some combination of these. If these soils are drained and cultivated using present technology, the organic materials will decompose either slowly or rapidly, depending on the management used and temperatures. Most of these soils in the United States support native vegetation. (Back to Fibrists key)

Saprists Great Groups

Saprists are the wet Histosols in which the organic materials are well decomposed. The botanic origin of the organic material is difficult to determine in most of these soils. The fiber content is less than one-sixth after rubbing between the thumb and fingers. Most of these soils have a bulk density of more than 0.2 g/cm^3.

Saprists occur in areas where the ground-water table tends to fluctuate within the soil or in areas where the soil was aerobic during drier periods in the past. They consist of the residue that remains after the aerobic decomposition of organic matter. When drained, fibric and hemic soil materials commonly decompose and form sapric soil materials. If the organic materials are deep and are drained either artificially or naturally, Fibrists and Hemists are converted after some decades to Saprists.



Profile of a Saprist (specifically a Haplosaprist) in Malaysia. This soil consists of well decomposed organic soil material.

(Back to Saprists)

Key to Great Groups of Saprists (Back to key to suborders)

Saprists that have:

1. **A sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon within a depth of 50 cm -------------------------- Sulfosaprists**
2. **Sulfidic materials (acid-producing, oxidizable sulfur compounds) within a depth of 100 cm -- Sulfisaprists**
3. **Cold average soil temperature ------------------------------------ Cryosaprists**
   These soils have a cryic soil temperature regime.
4. **Organic materials originating from woody, mossy, grassy, or herbaceous botanical sources --------------------------------- Haplosaprists**

Descriptions of Great Groups of Saprists

Sulfosaprists—These are the acid sulfate soils that consist of organic soil materials. They have a sulfuric horizon that formed as a result of draining soil which contain sulfidic materials. They are extremely acid and are toxic to most plants. They are mainly in drained coastal marshes or deltas near the mouths of rivers that carry sediments containing few or no carbonates. Most of these soils have an appreciable amount of mineral material within the control section. (Back to Saprists key)

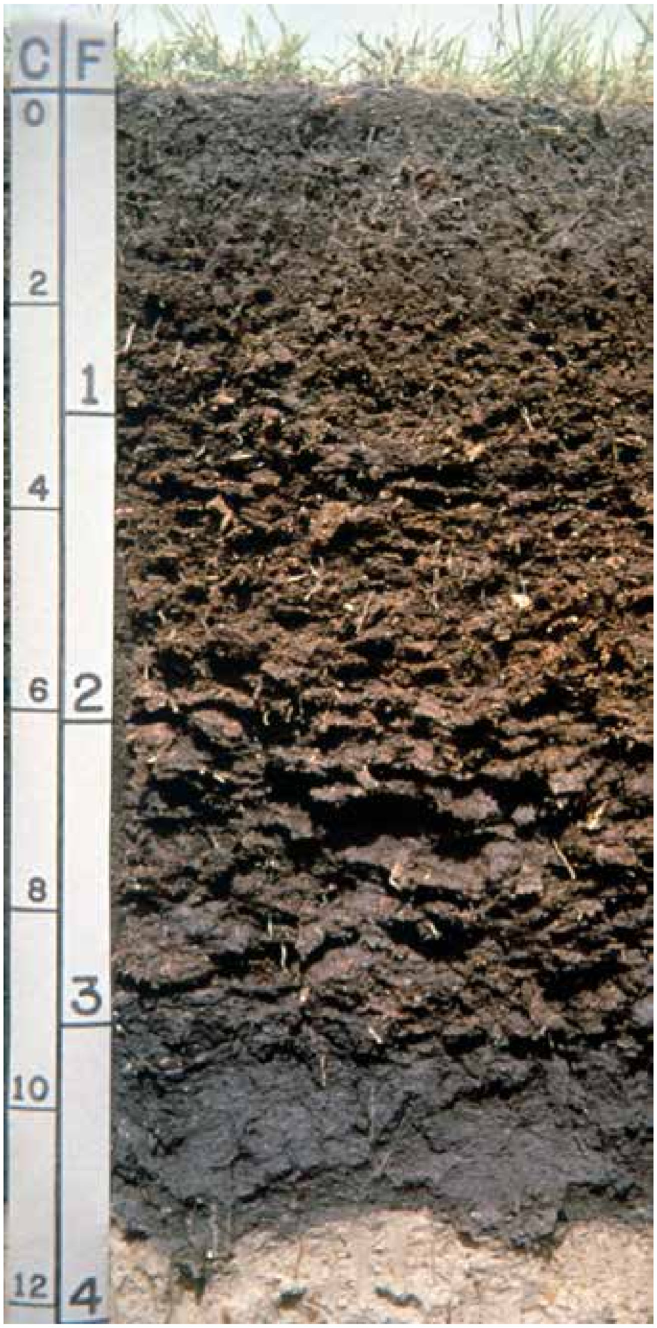
Sulfisaprists—These are the potentially acid sulfate soils that consist of organic soil materials. They have sulfidic materials within a depth of 100 cm and have not been drained. They occur mainly in coastal marshes near the mouths of rivers or in the deltas of rivers that carry sediments with a low content of carbonates. These soils are locally extensive in the coastal marshes and deltas of some large rivers that drain humid regions. (Back to Saprists key)

Cryosaprists—These are the cold Saprists that do not have a sulfuric horizon with its upper boundary within a depth of 50 cm and do not have sulfidic materials within a depth of 100 cm. They have a cryic temperature regime. These soils formed from many kinds of plant materials, including wood, moss, grass, and herbaceous materials. Some of these soils freeze during winter, and some do not. Those that do not freeze are insulated by snow cover or have a marine climate in which winters are mild and summers are very cool. If these soils are used as cropland, low soil temperatures in summer limit their suitability for crops. Most of these soils support native coniferous forest vegetation. (Back to Saprists key)]

Organic soil materials make up the Cryosaprist in the left photo which blankets the part of the Alaskan landscape shown in the right photo. The upper 10 cm of the profile consists of slightly decomposed fibric material (reddish sphagnum), the middle 18 cm is moderately decomposed hemic material, and the lower 15 cm is highly decomposed sapric material. (Photo courtesy of John Kelley)

Return to Cryosaprists

Haplosaprists—These Saprists are composed of organic materials derived from many kinds of plant materials, including wood, moss, grass, and herbaceous materials. If these soils are drained and cultivated using present technology, the organic materials decompose and disappear slowly or rapidly, depending on the management used and temperatures. Eventually, within some decades, the Haplosaprists that are drained and cultivated will convert to mineral soils. This conversion has been observed in the United States. Many Haplosaprists support native vegetation, mostly forest plants or shrubs and grass-like plants. Many areas are cleared, drained, and used as cropland. Some Haplosaprists are saline due to their proximity to coastal areas that are occasionally inundated by the ocean. (Back to Saprists key)



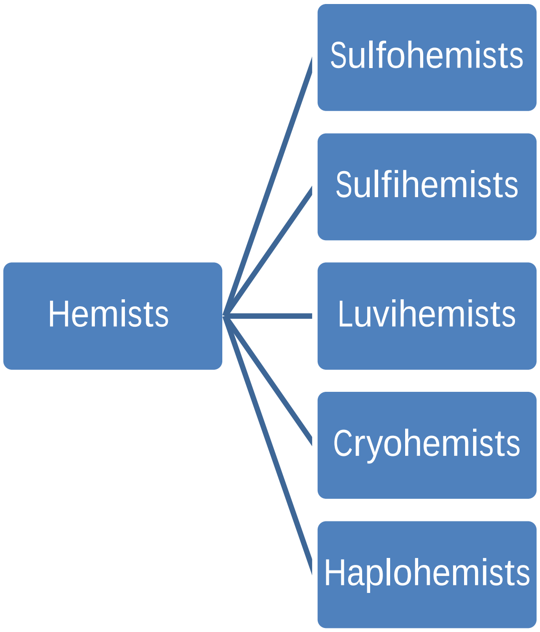
Profile of a poorly drained Haplosaprist that formed in a low-lying marsh in the northern United States. The upper 3 feet is composed of decaying organic soil material. Mineral layers consisting of black loam (between depths of 3 and 4 feet) and gray sandy loam (below 4 feet) underlie the organic layers in this profile. The mineral layers are glacial outwash deposits.

Return to Haplosaprists

Hemists Great Groups

Hemists are the wet Histosols in which the organic materials are moderately decomposed. The botanic origin of much of the organic material cannot be readily determined. The fiber content of much of the organic material is between one-sixth and two-thirds after rubbing between the thumb and fingers. The bulk density commonly is between 0.1 and 0.2 g/cm^3. Ground water is at or very close to the soil surface much of the time unless artificial drainage is provided. The level of ground water may fluctuate but seldom drops below about 30 cm.

Hemists occur in areas ranging from the Equator to the high latitudes. They are in closed depressions and in broad flat areas, such as coastal plains and outwash plains. Most Hemists are under natural vegetation and are used as woodland, rangeland, or wildlife habitat. Some large areas of Hemists are cleared, drained, and used as cropland.



Key to Great Groups of Hemists (Back to key to suborders)

Hemists that have:

1. **A sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon within a depth of 50 cm -------------------------- Sulfohemists**
2. **Sulfidic materials (acid-producing, oxidizable sulfur compounds) within a depth of 100 cm -- Sulfihemists**
3. **A horizon ≥ 2 cm thick composed of ≥ 50% humilluvic material (illuviated humus) -- Luvihemists**
4. **Cold average soil temperature ------------------------------------ Cryohemists**
   These soils have a cryic soil temperature regime.
5. **Organic materials originating from herbaceous, moss, grass, or woody botanical sources -- Haplohemists**

Descriptions of Great Groups of Hemists

Sulfohemists—These are the Hemists that have a sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon within a depth of 50 cm. The sulfuric horizon formed as a consequence of draining soil containing sulfidic materials. Sulfohemists are extremely acid and are toxic to most plants. Most are nearly black and have straw-colored concentrations of iron sulfate (jarosite) within a depth of 50 cm. These soils are mainly in drained coastal marshes or deltas near the mouths of rivers that carry sediments having a low content of carbonates. Most have an appreciable amount of mixed-in mineral material. They support sparse vegetation, mostly forbs and grass-like plants. They are used mainly as recreational areas or wildlife habitat. (Back to Hemists key)

Sulfihemists—These are the Hemists that have sulfidic materials (acid-producing, oxidizable sulfur compounds) within a depth of 100 cm. They are potentially extremely acid or ultra acid. Most Sulfihemists will develop a sulfuric horizon and become Sulfohemists if they are artificially drained to an extent that oxygen is allowed to reach the sulfidic materials. These soils are permitted to have more fiber than other Hemists. They are locally extensive and occur mainly in coastal marshes near the mouths of rivers or in the deltas of rivers that carry sediments having a low content of carbonates. Most Sulfihemists support native vegetation, mainly forbs and grass-like plants. (Back to Hemists key)

Luvihemists—These soils are not known to occur in the United States, but the great group is provided tentatively for use in other countries. These are the Hemists that have a horizon 2 cm or more thick in which humilluvic material (illuviated humus) constitutes one-half or more of the volume. Because Luvihemists cannot be studied in the United States, a precise description of these soils is not provided. It should be noted, however, that these soils are typically acid and have been cultivated for a long time. (Back to Hemists key)

Cryohemists—These are the cold Hemists that have a cryic temperature regime. The fibers in these soils are from many kinds of plant materials, including wood, moss, grass, and herbaceous materials. Some of these soils freeze during winter, and some do not. Those that do not freeze are insulated by snow cover or have a marine climate in which winters are mild and summers are very cool. If these soils are used as cropland, low soil temperatures in summer limit their suitability for crops. Most of these soils support native coniferous forest vegetation. (Back to Hemists key)

Haplohemists—Most Haplohemists are saturated for considerably longer than 30 cumulative days per year. The organic materials in these soils are from many kinds of plant materials, including wood, moss, grass, and herbaceous materials. If these soils are drained and cultivated using present technology, the organic materials decompose and disappear slowly or rapidly, depending on the management used and temperatures. Eventually, within some decades, the Haplohemists that are drained and cultivated will convert to Saprists and then to mineral soils. Most Haplohemists support native vegetation, mostly forest plants or shrubs and grass-like plants. Some large areas are cleared, drained, and used as cropland. (Back to Hemists key)

Inceptisols Order

Inceptisols are youthful soils with a weak, but noticeable, degree of profile development.

General Characteristics

Inceptisols have profiles that are more strongly developed than those of the Entisols but are too weakly developed to meet the criteria for any of the other soil orders. As a consequence, Inceptisols include a diverse collection of soils. The feature common to all Inceptisols is a relatively weak degree of development. Inceptisols are most commonly characterized by a soil profile with an ochric (typically thin and/or light-colored) epipedon and a cambic (minimal soil development) subsoil horizon. However, there are many exceptions. Inceptisols can have a wide range in kinds of surface and subsoil horizons. These horizons commonly include, but are not limited to, an umbric (humus-rich with low base saturation) epipedon, a histic (wet, organic surface layer) epipedon, a calcic (calcium carbonate accumulation) horizon, a petrocalcic (cemented by calcium carbonate) horizon, a duripan (layer cemented by silica), a fragipan (firm and brittle but not cemented layer), and sulfuric (highly acid due to oxidation and production of sulfuric acid) subsoil horizons.

Environment and Processes

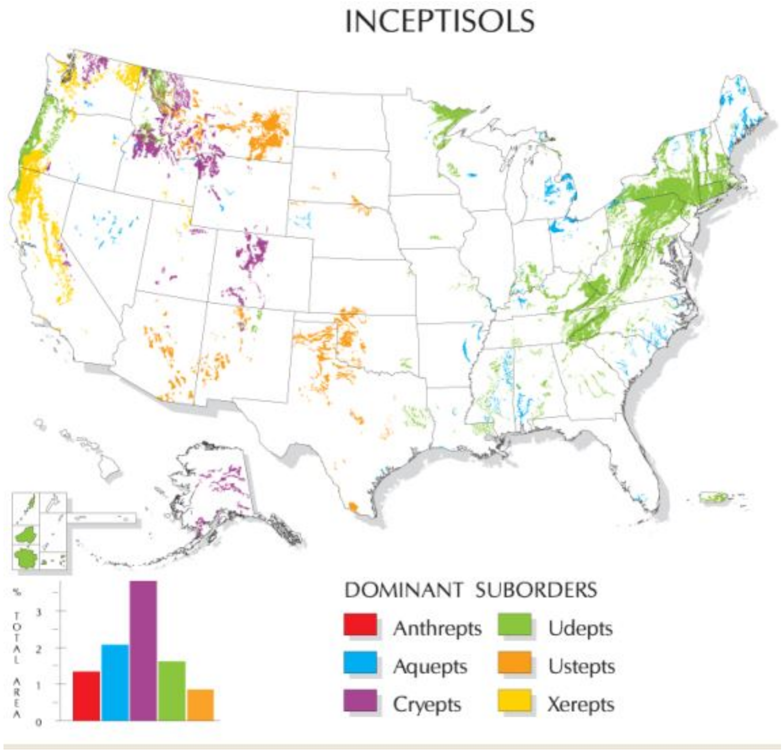
In general, Inceptisols occur on relatively young geomorphic surfaces that are sufficiently stable to allow weak but noticeable profile development. Typical settings include upland slopes, flood plains, stream terraces, and glacial till and outwash plains. Inceptisols are very poorly drained to excessively drained. They are found in diverse environmental settings, ranging from tropics to tundra and from humid to semiarid climates. However, Inceptisols by definition cannot have an aridic soil moisture regime or permafrost and thus are excluded from most deserts and many very cold regions.

Location

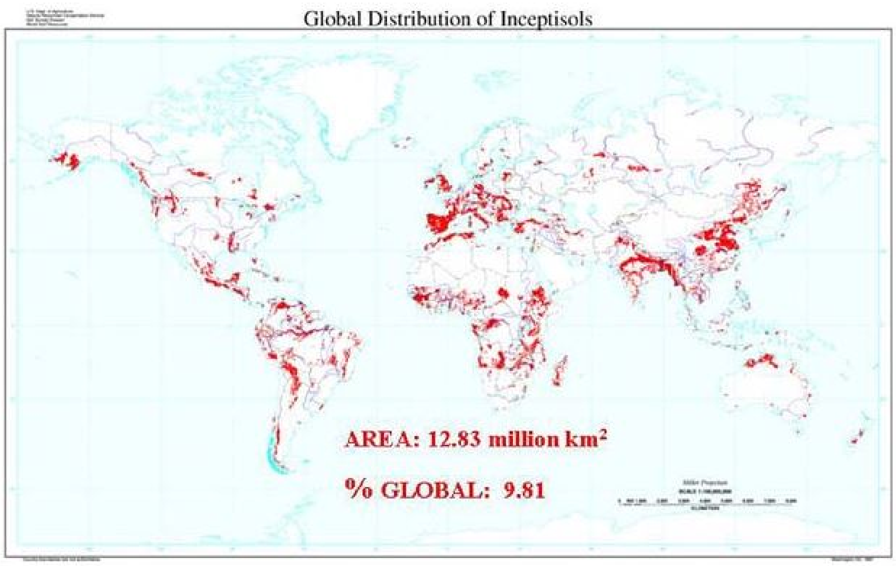
Globally, Inceptisols occupy about 17% of the ice-free land area. They are found throughout the world and in all regions of the United States, with the abovementioned exclusions (deserts and permafrost-affected areas).

Profile of an Inceptisol.

(Back to Key to Soil Orders)



Inceptisols by suborder in the United States. Note: This map was produced before the introduction of the Gelepts suborder and the deletion of the Anthrepts suborder. Some areas shown as Cryepts in Alaska are now Gelepts. Anthrepts are now distributed among the other suborders.



Global distribution of Inceptisols.

Inceptisols Suborders

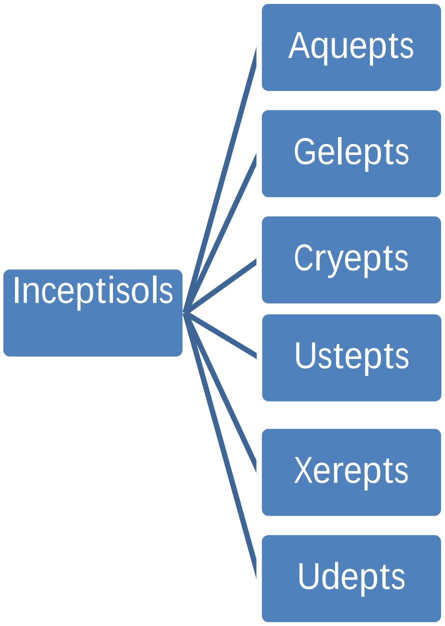
Classification of Inceptisols

In the definitions of the suborders, emphasis is placed on soil climate in the form of soil wetness (Aquepts), cold soil temperature (Gelepts and Cryepts), and soil moisture regime (Ustepts, Xerepts, and Udepts).

The great group level reflects a combination of important properties, including the presence of a diagnostic horizon (other than the minimally developed ochric epipedon or cambic subsoil horizon), cold soil temperature, patterns of soil saturation, presence of plinthite (iron-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles), significant levels of sodium and other soluble salts, base saturation level, and intense bioturbation from earthworms or other organisms.

The six suborders are:

1. Aquepts—wet Inceptisols (aquic conditions in the upper part)
2. Gelepts—very cold Inceptisols that lack permafrost (gelic temperature regime)
3. Cryepts—cold Inceptisols (cryic temperature regime)
4. Ustepts—moderately dry Inceptisols (limited moisture)
5. Xerepts—moderately dry Inceptisols (limited moisture that is supplied in winter and Mediterranean-type climate)
6. Udepts—Inceptisols of humid regions with well-distributed rainfall



Key to Suborders of Inceptisols

Inceptisols that have:

1. **Either:**

   a. A seasonal high water table within a depth of 50 cm,
   This item requires either a histic epipedon (wet, organic surface layer), a sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon within a depth of 50 cm, or redoximorphic features (gray and red color patterns) within a depth of 50 cm. See 12th edition of "Keys to Soil Taxonomy" for specific color requirements).

   OR

   b. A seasonal high water table within a depth of 100 cm and high levels of sodium within a depth of 50 cm --------------------------- Aquepts
   This item requires an exchangeable sodium percentage of ≥ 15 or a sodium adsorption ratio of ≥ 13.

2. **Very cold average soil temperature ------------------------------------ Gelepts**
   These soils have a gelic soil temperature regime.

3. **Cold average soil temperature -- Cryepts**
   These soils have a cryic soil temperature regime.

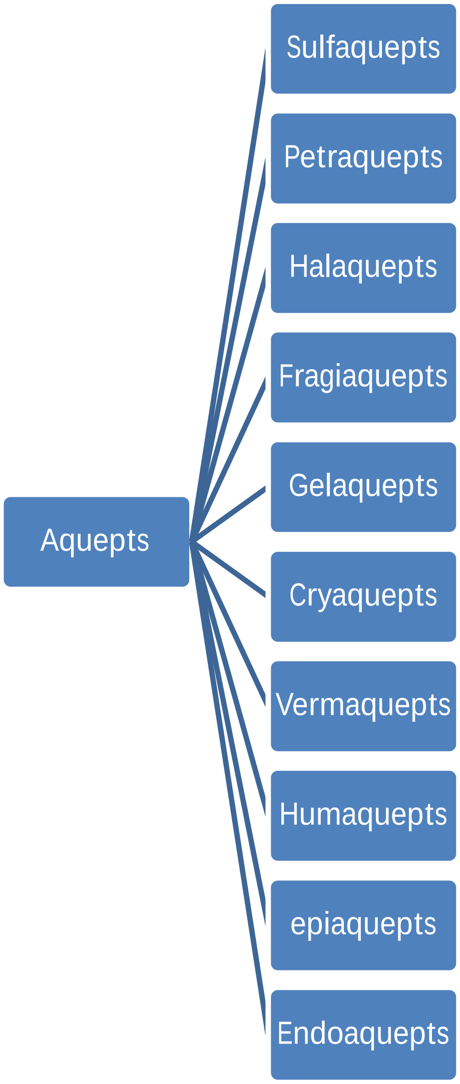
4. **Somewhat limited soil moisture available for plant growth -- Ustepts**
   These soils have an ustic soil moisture regime. Moisture is limited, but available, during portions of the growing season.

5. **A Mediterranean-type climate -- Xerepts**
   These soils have a xeric soil moisture regime (cool and moist in winter and warm and dry in summer).

6. **Seasonally well-distributed precipitation ----------------------------- Udepts**
   These soils have a udic soil moisture regime.

Aquepts Great Groups

Aquepts are the wet Inceptisols. These soils have poor or very poor natural drainage. If the soils are not artificially drained, ground water is at or near the soil surface at some time during most years but typically not during all seasons. These soils are saturated long enough to become devoid of oxygen (aquic conditions). They generally have a gray to black surface horizon and a gray subsurface horizon with redoximorphic concentrations (reddish to black accumulations of iron-manganese oxides) that begins at a depth of less than 50 cm. A few of the soils have a brownish surface horizon that is less than 50 cm thick. Most Aquepts formed in late-Pleistocene or younger deposits in depressions, on nearly level plains, or on flood plains. They occur in areas ranging from the Equator to latitudes with discontinuous permafrost. The common features of most of these soils are the redoximorphic features (gray and red color patterns) at a depth of 50 cm or less and, unless the soils have been artificially drained, shallow ground water. Most of the soils have a cambic (minimal soil development) horizon, and some have a fragipan (firm and brittle but not cemented layer). Some may have a human-made plaggen epipedon.


Aquepts
Sulfaquepts
Petraquepts
Halaquepts
Fragiaquepts
Gelaquepts
Cryaquepts
Vermaquepts
Humaquepts
epiaquepts
Endoaquepts

Profile of an Aquept (specifically a Humaquept) in Maine. The soil has an umbric epipedon extending to a depth of about 13 inches and a gray cambic horizon with redoximorphic features extending to depths below the base of the photo. Scale is in feet.

(Back to Aquepts)

Key to Great Groups of Aquepts (Back to key to suborders)

Aquepts that have:

1. **A sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon within a depth of 50 cm --------------------------- Sulfaquepts**
   Begin measuring depth below any O horizon.

2. **A cemented horizon (or plinthite) within a depth of 100 cm --- Petraquepts**
   The cemented portion (or plinthite) is ≥ 50% of the horizon. Plinthite is an iron-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles. Begin measuring depth below any O horizon.

3. **A salic (high salinity) horizon or a high sodium content within a depth of 50 cm -- Halaquepts**
   These soils either have a salic (high content of salts) horizon or have an exchangeable sodium percentage of ≥ 15 (or a sodium absorption ratio of ≥ 13) in a layer ≥ 25 cm thick. Begin measuring depth below any O horizon.

4. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm --- Fragiaquepts**
   Begin measuring depth below any O horizon.

5. **Very cold average soil temperature ------------------------------ Gelaquepts**
   These soils have a gelic soil temperature regime.

6. **Cold average soil temperature-------------------------------------- Cryaquepts**
   These soils have a cryic soil temperature regime.

7. **Significant evidence of bioturbation within a depth of 100 cm --- Vermaquepts**
   One or more layers ≥ 25 cm thick (cumulative) must have ≥ 25%, by volume, evidence of bioturbation. Begin measuring depth below any O horizon.

8. **A thick, dark-colored, humus-rich, surface horizon ------- Humaquepts**
   These soils have either a histic (wet, organic surface layer), melanic (dark and humus-rich with andic properties), mollic (rich in humus and bases), or umbric (humus-rich with low base saturation) epipedon.

9. **Episaturation (perched water table) ------------------------------ Epiaquepts**

10. **Endosaturation (saturated throughout the profile) -------- Endoaquepts**

Descriptions of Great Groups of Aquepts

Sulfaquepts—These are acid sulfate soils that have been drained and oxidized at some time. They are extremely acid and toxic to most plants. They are mostly dark gray and have straw-colored mottles of iron sulfate (jarosite) within a depth of 50 cm. They are mainly in drained coastal marshes near the mouths of rivers that carry sediments that are free of carbonates or have a low content of carbonates. They can have any texture, but most are loamy or clayey. These soils contain an appreciable amount of organic carbon (of Holocene age). They are rare in the United States but occur elsewhere in a few areas that have been used mainly for the production of rice. (Back to Aquepts key)

Profile of a poorly drained Sulfaquept in Korea. This soil is used to grow rice. The right side of the profile has been smoothed; the left side shows the natural soil structure. Draining the soil has caused sulfur within the soil to oxidize, thereby forming sulfuric acid. The yellow streaks below a depth of about 30 cm are concentrations of the mineral jarosite, which is produced as the sulfur is oxidized. Scale is in 10-cm increments.

Return to Sulfaquepts

Petraquepts—These soils have one or more horizons, within a depth of 100 cm, in which plinthite (firm, iron oxide-rich concentration) or a cemented or indurated diagnostic horizon either forms a continuous phase or constitutes one-half or more of the volume. The layer of plinthite and the placic (cemented by iron and organic matter) horizon are the only horizons known to occur in the Petraquepts in the United States. Some Petraquepts may have a duripan (layer cemented by silica) or a petrocalcic (cemented by calcium carbonate) horizon. Petraquepts have a ground water table that fluctuates considerably during the year, between a level at or near the soil surface during the rainy season to a much lower level during less wet seasons. A histic (wet, organic surface layer) or umbric (humus-rich with low base saturation) epipedon and a cambic (minimal soil development) subsoil horizon may be present. In some of the soils, the placic horizon is so close to the soil surface that there is no cambic horizon above it. Petraquepts are in areas of very high rainfall. The vegetation may be rainforest, *Sphagnum*, or other water-loving plants. Temperatures range from cold to very warm. Slopes generally are such that water does not pond on the surface, but high rainfall keeps some of the soils continuously wet. Petraquepts are rare in the world. (Back to Aquepts key)

Halaquepts—These are saline or sodic soils that have both a seasonal high water table and a period in which capillary rise and evapotranspiration bring sodium or other salts to or near the soil surface. Salt efflorescence on the soil surface is common in dry seasons. Halaquepts typically have grayish colors, and some have redoximorphic concentrations (reddish to black accumulations of iron-manganese oxides) from near the soil surface downward. Nearly all are level and formed in Holocene alluvium. The native vegetation is mostly sedges and salt-tolerant grasses and shrubs, but some of the soils have been artificially drained and are used as irrigated cropland. Halaquepts are not extensive in the United States. (Back to Aquepts key)

Fragiaquepts—These soils have a fragipan (firm and brittle but not cemented layer) that is within a depth of 100 cm and commonly at a depth of 30 to 50 cm. Typically, the water table is perched on the fragipan. The horizons above the pan are grayish and are saturated with water during some period in most years. Most of these soils have forest vegetation, but a few areas have been cleared. The trees have a shallow root system and are particularly subject to windthrow. A distinct microrelief of 50 to 60 cm or more is very common above the pan. The upper surface of the pan generally is smooth. In many areas of these soils, the horizons above the fragipan appear to have been mixed by the uplift of the roots of fallen trees. In some areas of mounds, the horizons above the pan consist of an organic O horizon, an ochric (typically thin and/or light-colored) epipedon, and an intermittent cambic (minimal soil development) subsoil horizon. In other areas, the cambic horizon is continuous. Most Fragiaquepts are nearly level or gently sloping and developed in Pleistocene-age sediments. The Fragiaquepts in the United States are mostly in areas with cool to moderate temperatures. They are moderately extensive in parts of the northeastern States, and a few occur in Oregon and Washington. (Back to Aquepts key)

Gelaquepts—These are the Aquepts of very cold regions. They have a gelic soil temperature regime but lack permafrost within the soil profile. They tend to have a high content of rock fragments, and some are shallow to bedrock. They are subject to wide variations in summer high temperatures and winter low temperatures, which result in mean annual soil temperatures of 0 degrees C or less, but without permafrost. (Back to Aquepts key)

Cryaquepts—These are the cold Aquepts. They typically have an ochric (typically thin and/or light-colored) or histic (wet, organic surface layer) epipedon over a cambic (minimal soil development) subsoil horizon. Cryaquepts are on flood plains, in depressional areas, and on plains. Most have grayish subsoils, and some are stratified. Cryaquepts formed mostly in late-Pleistocene or recent sediments south of the continuous permafrost zone. Most support mixed forest, shrub, or grassy vegetation. Many are nearly level, but some in areas of high precipitation have strong slopes. Because Cryaquepts are both cold and wet, they have low potential for cropping. They are of moderate extent in the high mountains and subarctic regions of North America and Eurasia. The major areas of the Cryaquepts in the United States are on the outwash plains and flood plains in Alaska. (Back to Aquepts key)

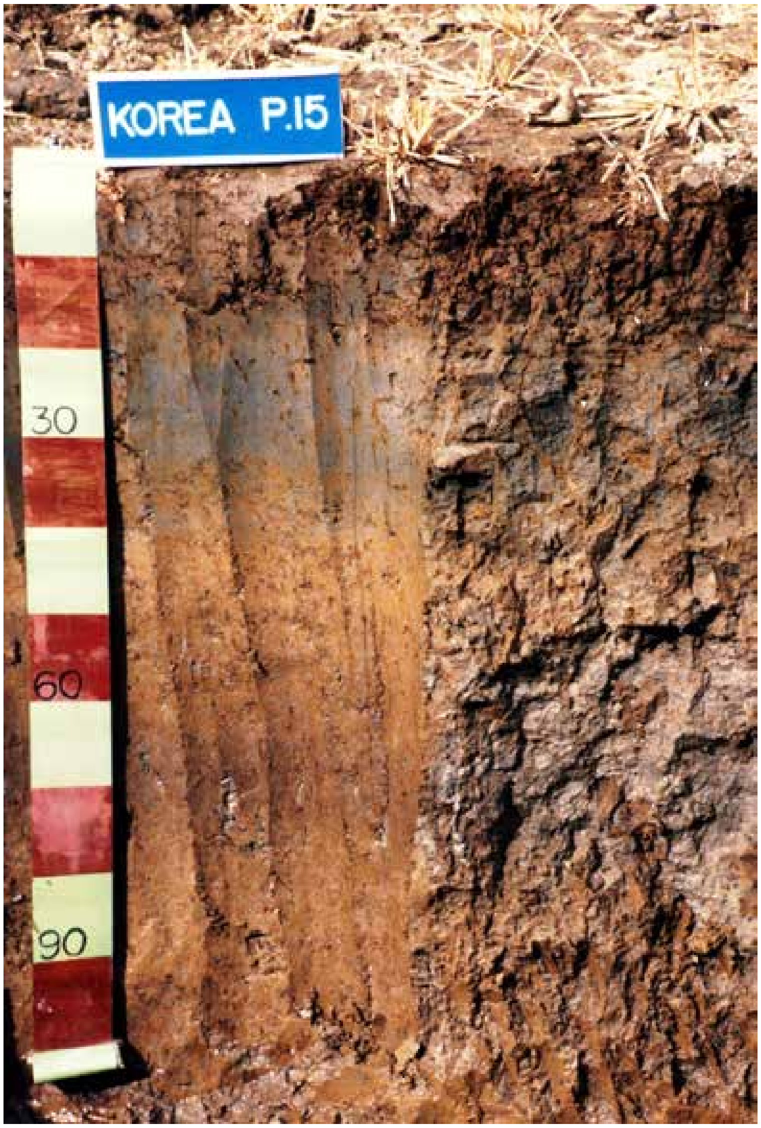
Profile of a poorly drained Cryaquept in Alaska. This soil has a histic epipedon about 38 cm thick. The upper 20 cm is derived from sphagnum moss, which can be seen growing on the surface, and is little decomposed. Darker, more highly decomposed organic material is at depths of 20 to 38 cm. Gray mineral soil material is below about 38 cm. The boundary between the organic and mineral layers is wavy to irregular due to mixing and folding from cryoturbation. Scale is in cm. (Photo courtesy of Dr. David Weindorf)

Return to Cryaquepts

Vermaquepts—These soils have recognizable bioturbation, such as filled animal burrows, wormholes, or casts. Krotovinas (filled animal burrows) restrict water movement because they are dense, massive, compact, and stratified. Significant amounts of krotovinas affect soil morphology, soil hydrology, and soil behavior. Vermaquepts are known to occur along the coastal plain of Texas and in other southeastern States. (Back to Aquepts key)

Humaquepts—These soils have a thick, dark-colored, humus-rich surface layer. They have either a histic (wet, organic surface layer), melanic (dark and humus-rich with andic properties), mollic (rich in humus and bases), or umbric (humus-rich with low base saturation) epipedon. The ground water commonly fluctuates from a level near the soil surface to below a depth of 50 cm. These soils have cool to warm soil temperatures. Before they were cultivated, most Humaquepts supported forest vegetation. Humaquepts are generally nearly level, and their parent materials are typically late-Pleistocene or younger sediments. These soils are of small extent in the United States. (Back to Aquepts key)

Epiaquepts—These soils have one or more layers in the upper part of the profile that are saturated for part of the year and underlain by unsaturated layers (a perched water table). They have cool to warm soil temperatures. Before cultivation, most Epiaquepts supported forest vegetation. Epiaquepts are generally nearly level or gently sloping, and their parent materials are typically late-Pleistocene or younger sediments. (Back to Aquepts key)



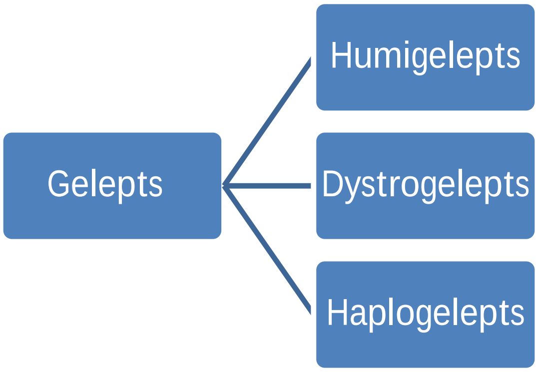
Profile of an Epiaquept used for paddy rice production in Korea. Compaction of the upper part of the soil facilitates puddling with irrigation water so that areas remain flooded while the crop matures. The gray colors between depths of about 15 and 30 cm are caused by the human-induced wet soil conditions, which in turn result in the chemical reduction of iron in the upper part of the soil. This soil has an ochric epipedon about 15 cm thick underlain by a cambic horizon that extends below the base of the photo. The left side of the profile has been smoothed; the right side retains the natural soil structure. Scale is in cm.

Return to Epiaquepts

Endoaquepts—These soils are saturated in all horizons throughout the profile for some time during the year (endosaturation). The ground water commonly fluctuates from a level near the soil surface to below a depth of 50 cm. These soils have cool to warm soil temperatures. Before they were cultivated, most Endoaquepts supported forest vegetation. Endoaquepts are generally nearly level, and their parent materials are typically late-Pleistocene or younger sediments. (Back to Aquepts key)

Gelepts Great Groups

Gelepts are the Inceptisols of very cold regions. These soils have a gelic soil temperature regime but lack permafrost within the soil profile. They tend to be in landscape positions that are subject to wide variations in summer high temperatures and winter low temperatures, which result in mean annual soil temperatures of 0 degrees C or less, but without permafrost.



Key to Great Groups of Gelepts (Back to key to suborders)

Gelepts that have:

1. **A thick, dark-colored, humus-rich, surface horizon -------- Humigelepts**
   These soils have an umbric (humus-rich with low base saturation) or mollic (rich in humus and bases) epipedon.

2. **Less than 50% base saturation within the upper 50 cm -- Dystrogelepts**
   Base saturation is determined by NH_4OAc lab method. Begin measuring depth below any O horizon. See 12th edition of "Keys to Soil Taxonomy" for detailed criteria regarding thickness and depth requirements.

3. **An ochric (typically thin and/or light-colored) epipedon and base saturation $\geq$ 50% within a depth of 50 cm -------------------- Haplogelepts**
   Base saturation is determined by NH_4OAc lab method. Begin measuring depth below any O horizon.

Descriptions of Great Groups of Gelepts

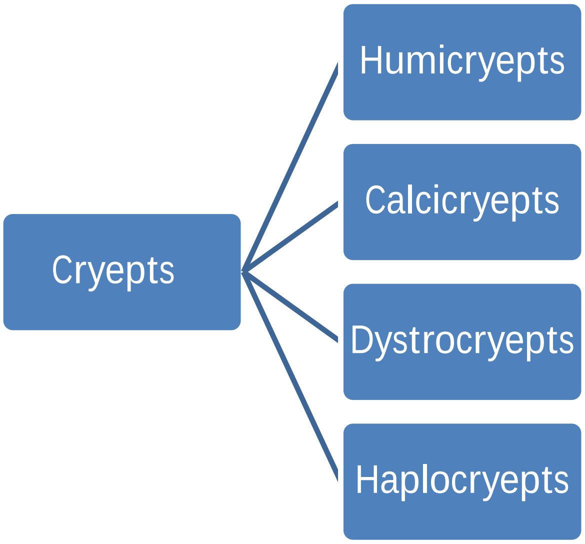
Humigelepts—These soils have a dark-colored, thick mollic (rich in humus and bases) or umbric (humus-rich with low base saturation) epipedon. The vegetation is mostly conifers or mixed conifers and hardwoods. Humigelepts may have formed in loess, drift, or alluvium or in solifluction deposits, mostly late Pleistocene or Holocene in age. They commonly have a thick, dark surface layer with a high content of organic matter and a brownish cambic (minimal soil development) subsoil horizon. Most have a high content of gravel in at least the lower part of the profile, and some have bedrock within a depth of 100 cm. (Back to Gelepts key)

Dystrogelepts—These soils have relatively low base saturation, and as a result, low natural fertility. The vegetation is mostly conifers or mixed conifers and hardwoods. Dystrogelepts may have formed in loess, drift, or alluvium or in solifluction deposits, mostly late Pleistocene or Holocene in age. They commonly have a thin, dark brownish ochric (typically thin and/or light-colored) epipedon and a brownish cambic (minimal soil development) subsoil horizon. Most have a high content of gravel in at least the lower part of the profile, and some have bedrock within a depth of 100 cm. (Back to Gelepts key)

Haplogelepts—These soils have an ochric (typically thin and/or light-colored) epipedon. They have relatively high base saturation, and as a result, high natural fertility. The vegetation is mostly conifers or mixed conifers and hardwoods. Haplogelepts may have formed in loess, drift, or alluvium or in solifluction deposits, mostly late Pleistocene or Holocene in age. They commonly have a thin, dark brownish ochric (typically thin and/or light-colored) epipedon and a brownish cambic (minimal soil development) subsoil horizon. Most have a high content of gravel in at least the lower part of the profile, and some have bedrock within a depth of 100 cm. (Back to Gelepts key)

Cryepts Great Groups

Cryepts are the cold Inceptisols of high-elevation mountains or high latitudes. The vegetation is mostly coniferous forest, subalpine meadow, shrub steppe, or tundra. Most of these soils are not cultivated. Cryepts formed in late Pleistocene or younger drift, colluvium, or alluvium on mountain slopes or valley floors. In areas with tephra, a layer near the surface that contains pumice fragments, volcanic glass, or amorphous weathering products of pyroclastic materials is common. These soils commonly have an ochric (typically thin and/or light-colored) or umbric (humus-rich with low base saturation) epipedon and a cambic (minimal soil development) subsoil horizon. Some have root-restricting bedrock or dense, compacted materials within a depth of 100 cm. Cryepts are moderately extensive in the United States. They occur in high-elevation mountains in the western States and in southern Alaska as well as in other mountainous areas of the world.



Key to Great Groups of Cryepts (Back to key to suborders)

Cryepts that have:

1. **A thick, dark-colored, humus-rich, surface horizon ------- Humicryepts**
   These soils may have an umbric (humus-rich with low base saturation) or mollic (rich in humus and bases) epipedon.

2. **A calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon within a depth of 100 cm -- Calcicryepts**
   Begin measuring depth below any O horizon.

3. **Base saturation of $\leq$ 50% in the upper 75 cm AND a lack of free carbonates within a depth of 200 cm -------------------------- Dystrocryepts**
   Base saturation is determined by NH_4OAc lab method. Begin measuring depth below any O horizon. See 12th edition of "Keys to Soil Taxonomy" for detailed criteria regarding thickness and depth requirements. Free carbonates will effervesce with dilute HCl.

4. **An ochric (typically thin and/or light-colored) epipedon and base saturation > 50% OR free carbonates within the profile -- Haplocryepts**
   Base saturation is determined by NH_4OAc lab method. Begin measuring depth below any O horizon. Free carbonates will effervesce with dilute HCl.

Descriptions of Great Groups of Cryepts

Humicryepts—These soils have a thick, dark umbric (humus-rich with low base saturation) or mollic (rich in humus and bases) epipedon. Humicryepts formed in deposits that are late Pleistocene or younger in age. They commonly have a dark brown surface layer and a brown cambic (minimal soil development) subsoil horizon. Some have root-restrictive bedrock or dense, compact material within a depth of 100 cm. The vegetation is mixed conifers, shrubs, or alpine meadow. These soils are of moderate extent in the high-elevation mountains of western United States and Alaska. They also occur in other parts of the world, mostly in mountainous areas. (Back to Cryepts key)

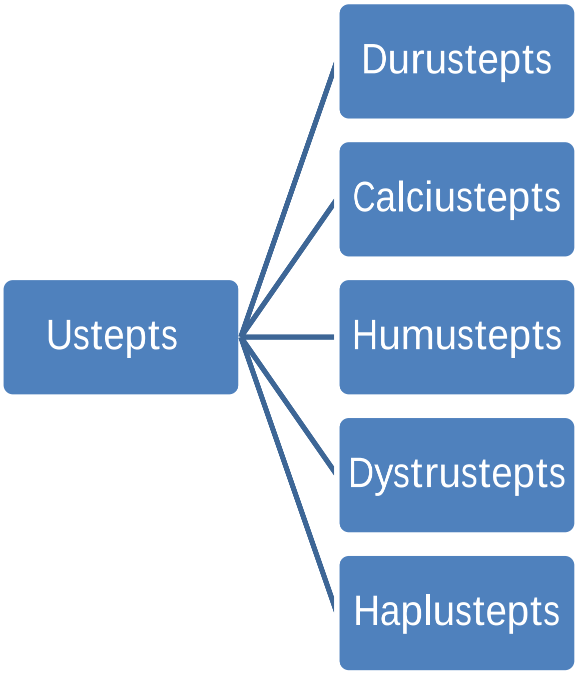
Calcicryepts—These soils have a calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) subsoil horizon within a depth of 100 cm. They formed in drift, alluvium, colluvium, or residuum, mostly late Pleistocene or Holocene in age. They may have a high calcium carbonate content due to the influence from calcareous sedimentary rocks, such as limestone in the parent materials. These soils commonly have a thin dark brown or brown ochric (typically thin and/or light-colored) epipedon and a brown cambic (minimal soil development) subsoil horizon. Some have bedrock within a depth of 100 cm. The natural vegetation is mostly grass and shrubs or coniferous forest with widely spaced trees. These soils are mainly used for timber production, wildlife habitat, or grazing by domestic livestock. Calcicryepts are of small extent and occur in high-elevation, inland mountainous regions in the western United States. (Back to Cryepts key)

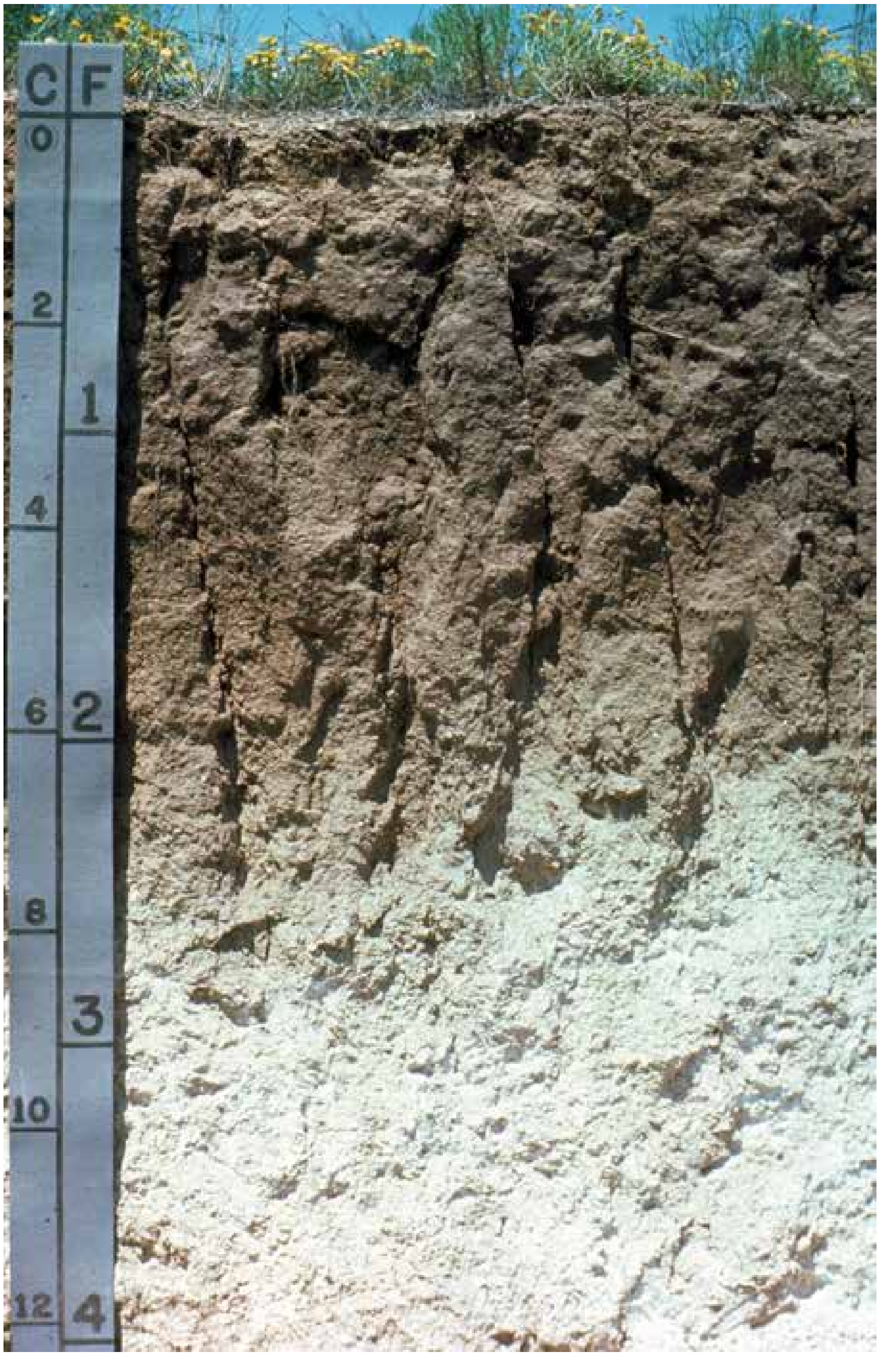
Dystrocryepts—These soils have low base saturation, and, as a result, relatively low natural fertility. They do not have free carbonates within a depth of 200 cm. They formed in drift, colluvium, alluvium, or loess (mostly late Pleistocene or Holocene in age) on mountain slopes and valley floors. Some have root-restrictive bedrock or dense, compact materials within a depth of 100 cm. These soils commonly have a thin, dark brown ochric (typically thin and/or light-colored) epipedon and a brown cambic (minimal soil development) subsoil horizon. Natural vegetation is mostly coniferous forest. In the United States, Dystrocryepts are moderately extensive in the high-elevation mountains of western States and in Alaska. They also occur in other mountainous areas of the world. (Back to Cryepts key)

Haplocryepts—These are the base-rich Cryepts that have free carbonates or base saturation of 50% or more. They formed in drift, colluvium, alluvium, or loess (late Pleistocene or Holocene in age). They commonly have a thin, dark brown ochric (typically thin and/or light-colored) epipedon and a brown cambic (minimal soil development) subsoil horizon. Some have root-restrictive bedrock within a depth of 100 cm. Natural vegetation is coniferous forest, mixed conifer and hardwood forest, or shrub steppe. These soils are used for wildlife habitat and livestock grazing in western States and are important agricultural soils in Alaska. They are extensive in Alaska and of small extent in the high-elevation inland mountains of western States. They also occur in other parts of the world, mostly in mountainous areas. (Back to Cryepts key)

Ustepts Great Groups

Ustepts are mainly the more or less freely drained Inceptisols of subhumid to semiarid regions. They have an ustic moisture regime (moisture is limited, but available, during portions of the growing season). They receive dominantly summer precipitation. They formed mostly in Pleistocene or Holocene deposits. Some of the soils with steep slopes formed in older deposits. Some Ustepts formed from Mollisols as a result of human-induced erosion of the former mollic epipedon, mostly through cultivation. Most Ustepts have an ochric (typically thin and/or light-colored) epipedon and a cambic (minimal soil development) subsoil horizon. Many are calcareous at a shallow depth and have an accumulation of calcium carbonate in the subsoil. A few have a duripan (layer cemented by silica) or an umbric (humus-rich with low base saturation) or mollic (rich in humus and bases) epipedon. The native vegetation commonly was grass, but some of the soils supported trees. Most of the soils are used as cropland or pasture. Ustepts are of moderate extent in the United States. They are most common on the Great Plains, mainly in Montana, Texas, and Oklahoma.





Profile of an Ustept (specifically a Calciustept) in Texas. This soil has an ochric epipedon about 6 cm thick, a cambic horizon (grayish brown) between depths of about 6 cm and 60 cm, and a calcic horizon (white) below.

Return to Ustepts

Key to Great Groups of Ustepts (Back to key to suborders)

Ustepts that have:

1. **A duripan (layer cemented by silica) within a depth of 100 cm -- Durustepts**
   Begin measuring depth below any O horizon.

2. **A calcic (calcium carbonate accumulation) horizon within a depth of 100 cm or a petrocalcic (cemented by calcium carbonate) horizon within a depth of 150 cm AND free carbonates or sandy texture above --- Calciustepts**
   Begin measuring depth below any O horizon. Free carbonates will effervesce with dilute HCl.

3. **A thick, dark-colored, humus-rich, surface horizon -------- Humustepts**
   These soils have an umbric (humus-rich with low base saturation) or mollic (rich in humus and bases) epipedon.

4. **Base saturation of ≤ 60% in the upper 75 cm AND a lack of free carbonates within a depth of 200 cm -------------------------- Dystrustepts**
   Base saturation is determined by NH_4OAc lab method. Begin measuring depth below any O horizon. Free carbonates will effervesce with dilute HCl.

5. **Base saturation of ≥ 60% in the upper 75 cm or free carbonates within a depth of 200 cm -- Haplustepts**
   Base saturation is determined by NH_4OAc lab method. Begin measuring depth below any O horizon. Free carbonates will effervesce with dilute HCl.

Descriptions of Great Groups of Usteps

Durustepts—These soils have a duripan (layer cemented by silica) within a depth of 100 cm. Commonly, they formed in the vicinity of volcanic cinders and ash falls. The parent materials are mainly volcanic tuffs, ash, cinders, and volcanic rocks. In the United States, the native vegetation is mostly grasses, shrubs, and trees. These soils are of small extent. Durustepts formed mainly in areas of Pleistocene deposits. They may be also on the leeward sides of some volcanic islands. (Back to Ustepts key)

Calciustepts—These soils have a calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon and are either calcareous or have a sandy texture in all overlying horizons. Precipitation has been insufficient to remove the carbonates from the upper horizons, or there is a continual external source of carbonates in dust or water. Calciustepts formed mostly in Pleistocene or older materials. On the Calciustepts in the United States, the vegetation was dominantly grass before the soils were cultivated. The soils are most extensive on the Great Plains in the United States but also occur in the intermountain valleys of the western States. (Back to Ustepts key)

Humustepts—These soils have a mollic (rich in humus and bases) or umbric (humus-rich with low base saturation) epipedon. Parent materials are mostly residuum, colluvium, or alluvium in mountain settings. Some have been influenced by volcanic ash. These soils commonly have a brownish cambic (minimal soil development) subsoil horizon. Some have root-limiting bedrock or a dense, compact layer in the profile. In the United States, Humustepts are found mostly in coastal California and in Hawaii. (Back to Ustepts key)

Profile of a well drained, gravelly Humustept in the Philippines. The soil formed in stratified layers of material, including volcanic ash. It has a dark, humus-rich umbric epipedon about 28 cm thick. Below this epipedon is a cambic horizon that extends to a depth of about 55 cm. Scale is in cm.

Return to Humustepts

Dystrustepts—These are the acid Ustepts with low base saturation and relatively low natural fertility. They developed mostly in Pleistocene or Holocene deposits. Some of the soils with steep slopes formed in older deposits. Parent materials generally are acid, moderately or weakly consolidated sedimentary or metamorphic rocks or acid sediments. The vegetation was mostly forest. Most of these soils have warm or very warm temperatures. A common horizon sequence in Dystrustepts is an ochric (typically thin and/or light-colored) epipedon over a cambic (minimal soil development) subsoil horizon. Some of the steeper soils are shallow to root-limiting bedrock or a dense, compact layer. In the United States, Dystrustepts are found mostly in coastal California and in Hawaii. A few are in the Rocky Mountains and on the Great Plains. (Back to Ustepts key)

Profile of a well drained, loamy Dystrustept in Thailand. This soil has an ochric epipedon about 12 to 15 cm thick underlain by a cambic subsoil horizon that extends to a depth of about 35 cm. A paralithic contact with soft, weathered bedrock is at a depth of about 35 cm. Scale is in cm.

Return to Dystrustepts

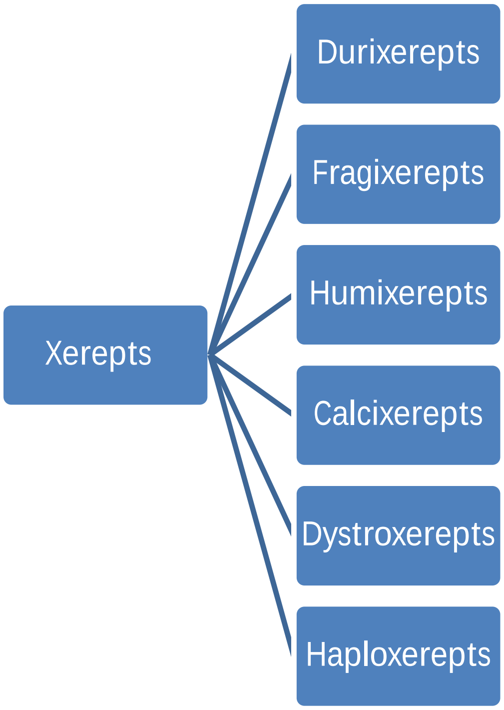
Haplustepts—These are the more or less freely drained Ustepts that are calcareous at some depth or have high base saturation. They commonly have an ochric (typically thin and/or light-colored) epipedon over a cambic (minimal soil development) subsoil horizon. Some have an accumulation of calcium carbonate in the subsoil. The native vegetation commonly was grass, but some of the soils supported trees. Haplustepts in the United States are mostly on the Great Plains. (Back to Ustepts key)

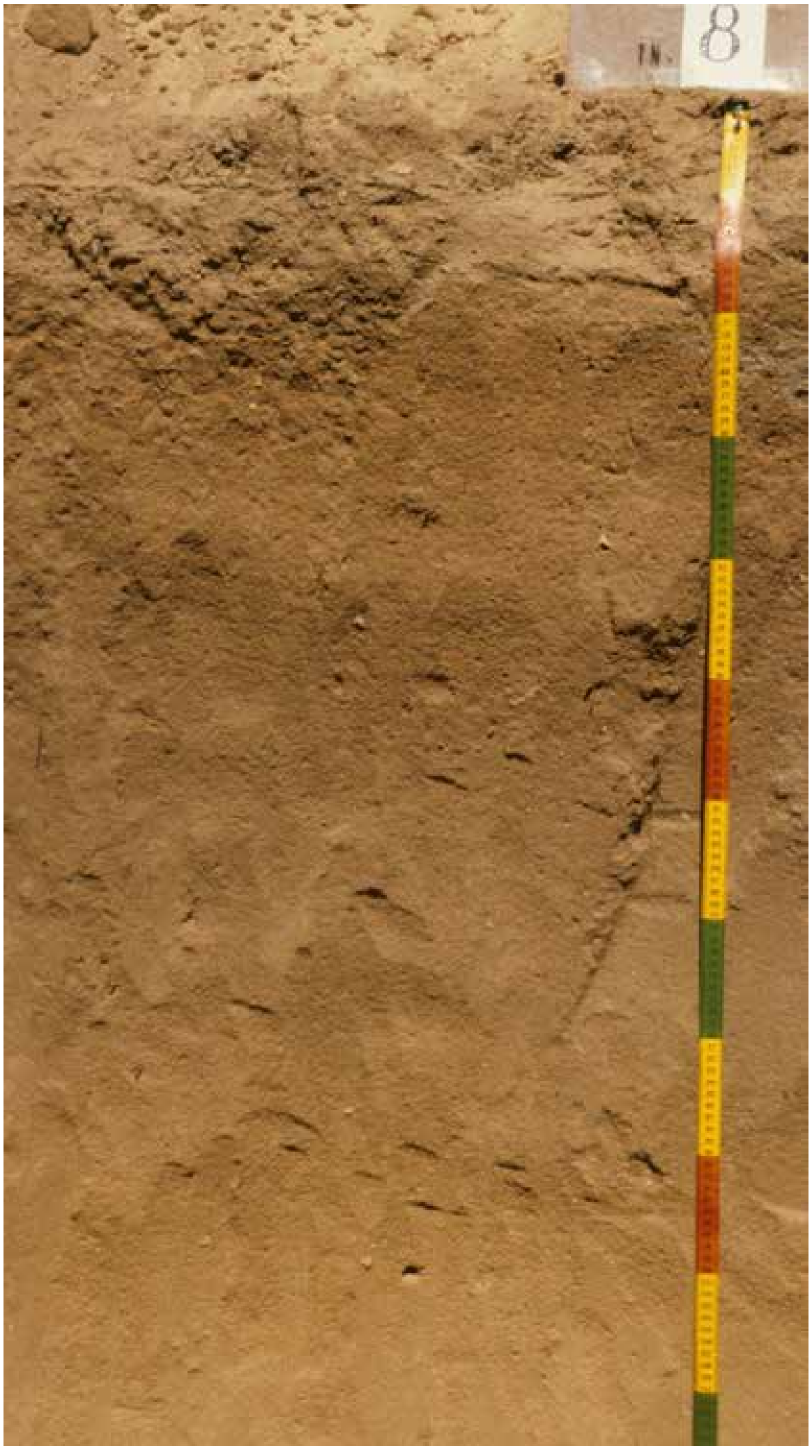
Profile of a moderately well drained Haplustept in Taiwan. This soil formed in stratified layers of loamy alluvium. An ochric epipedon extends to a depth of about 30 cm. Below this is a cambic horizon that extends to about 80 cm. The gray and red colors below a depth of about 80 cm are redoximorphic features that formed due to saturation with water and reduction of iron. The profile has been smoothed on the right side of the scale. There is a water table at the base of the profile.

Return to Haplustepts

Xerepts Great Groups

Xerepts are in regions that have Mediterranean-type climates, characterized by cool, moist winters and warm, dry summers. As their name implies, they have a xeric soil moisture regime. These soils are dry for extended periods in summer, but moisture moves through most of the soils in winter and is stored throughout the soil profile above the deep layers or above bedrock in most years. Xerepts formed mostly in Pleistocene or Holocene deposits. Some of the soils, mostly those with steep slopes, formed in older deposits. Most of the soils have an ochric (typically thin and/or light-colored) epipedon and a cambic (minimal soil development) subsoil horizon. Some have an umbric (humus-rich with low base saturation) or mollic (rich in humus and bases) epipedon or a duripan (layer cemented by silica) in the subsoil. A few have a fragipan (firm and brittle but not cemented layer). Some are calcareous at a shallow depth and have an accumulation of calcium carbonate in the subsoil. The native vegetation commonly is coniferous forest on the colder sites and shrubs, grass, and widely spaced trees on the warmer sites. Xerepts are of moderate extent in the United States. They are most common in the States of California, Oregon, Washington, Idaho, and Utah.





Profile of a Xerept (specifically a Haploxerept) in Tunisia. This soil has a reddish brown cambic horizon between depths of about 10 and 60 cm. Scale is in cm.

(Back to Xerepts)

Key to Great Groups of Xerepts (Back to key to suborders)

Xerepts that have:

1. **A duripan (layer cemented by silica) within a depth of 100 cm --- Durixerepts**
   Begin measuring depth below any O horizon.

2. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm --- Fragixerepts**
   Begin measuring depth below any O horizon.

3. **A thick, dark-colored, humus-rich, surface horizon ------- Humixerepts**
   These soils have an umbric (humus-rich with low base saturation) or mollic (rich in humus and bases) epipedon.

4. **A calcic (calcium carbonate accumulation) horizon within a depth of 100 cm or a petrocalcic (cemented by calcium carbonate) horizon within a depth of 150 cm AND free carbonates above ----- Calcixerepts**
   Begin measuring depth below any O horizon. Free carbonates will effervesce with dilute HCl.

5. **Base saturation of $\leq$ 60% in the upper 75 cm AND a lack of free carbonates within a depth of 200 cm ------------------------- Dystroxerepts**
   Base saturation is determined by NH_4OAc lab method. Begin measuring depth below any O horizon. Free carbonates will effervesce with dilute HCl.

6. **Base saturation of $\geq$ 60% in the upper 75 cm OR free carbonates within a depth of 200 cm -- Haploxerepts**
   Base saturation is determined by NH_4OAc lab method. Begin measuring depth below any O horizon. Free carbonates will effervesce with dilute HCl.

Descriptions of Great Groups of Xerepts

Durixerepts—These soils have a duripan (layer cemented by silica) within a depth of 100 cm. They have a Mediterranean-type climate and receive a large part of their annual precipitation in winter. Commonly, water is perched above the duripan for part of winter or early spring. The vegetation was commonly a coniferous forest or a mixture of grasses and scattered trees. Durixerepts are not extensive in the United States as a whole but are extensive locally. (Back to Xerepts key)

Fragixerepts—These soils have a fragipan (firm and brittle but not cemented layer) within a depth of 100 cm. Commonly, they have a brownish cambic (minimal soil development) subsoil horizon that is underlain by a fragipan at a depth of about 70 cm. Most Fragixerepts have perched water above the pan in winter, and few roots penetrate the pan. Consequently, plants on these soils tend to have shallow root systems. Many Fragixerepts formed in late-Pleistocene deposits. They have mostly gentle or moderate slopes, but some are steep. Most of these soils are loamy and have been leached of any free carbonates. The Fragixerepts in the United States are mostly in Idaho and Oregon and are of small extent. (Back to Xerepts key)

Humixerepts—These soils commonly have an umbric (humus-rich with low base saturation) epipedon. A few may have a mollic (rich in humus and bases) epipedon. They have a cambic (minimal soil development) subsoil horizon, and some have bedrock within the profile. They formed mostly in residuum, colluvium, or mudflow deposits on mountain slopes, terraces, or outwash plains. Many also have an influence from volcanic ash. The vegetation includes trees, grasses, pasture, and cropland. Humixerepts are commonly found in the western United States, in areas ranging from California to Washington and Idaho. (Back to Xerepts key)

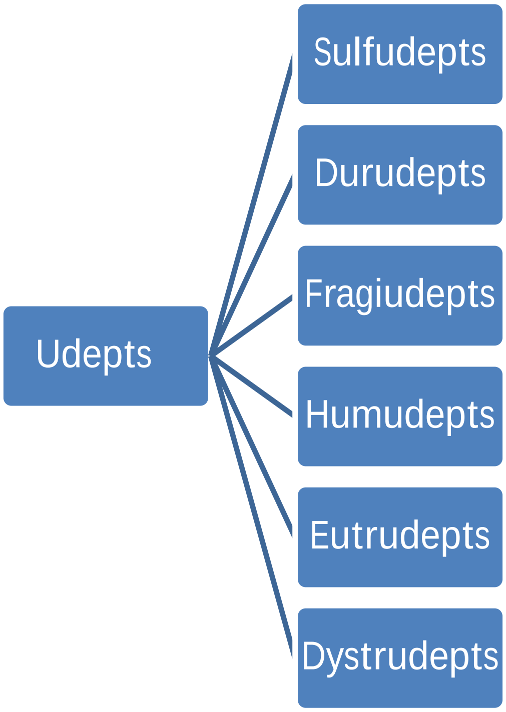
Calcixerepts—These soils have a calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon. They are calcareous in all overlying horizons. Either the parent materials had more carbonates than rainfall could remove from the upper horizons, or there is a continual external source of carbonates in dust or water. Calcixerepts formed mostly in Pleistocene sediments or younger materials on surfaces of comparable age. In the United States, the vegetation was dominantly grass and shrubs before the soils were cultivated. Calcixerepts are most extensive in California, Idaho, and Utah. (Back to Xerepts key)

Dystroxerepts—These are the acid Xerepts with relatively low base saturation and natural fertility. They developed mostly in Pleistocene or Holocene deposits. Some of the soils with steep slopes formed in older deposits. The typical horizon sequence in Dystroxerepts is an ochric (typically thin and/or light-colored) epipedon over a cambic (minimal soil development) subsoil horizon. Some of the steep Dystroxerepts are shallow to root-restricting bedrock or dense, compact materials. The parent materials generally are acid, moderately or weakly consolidated sedimentary or metamorphic rocks or acid sediments and commonly contain additions of volcanic ash near the surface. A few of the soils formed in saprolite derived from igneous rocks. The vegetation was mostly coniferous trees. Most Dystroxerepts are used as forest or pasture. Some, mostly the least sloping ones, are used as cropland. Dystroxerepts are extensive in the States of California, Washington, and Oregon. (Back to Xerepts key)

Haploxerepts—These soils are calcareous at some depth or have high base saturation. They are relatively high in natural fertility. Some of the soils have an accumulation of calcium carbonate in the subsoil. Haploxerepts are moist through winter and into spring but are thoroughly dry for much of the summer. Slopes are gentle to very steep, and the soils are shallow to very deep. The most common vegetation on Haploxerepts in the United States was coniferous forest on the cooler sites and grass and widely spaced trees on the warmer sites. Haploxerepts occur in the western United States and are moderately extensive. (Back to Xerepts key)

Udepts Great Groups

Udepts are mainly the more or less freely drained Inceptisols of humid climates. They formed on nearly level to steep surfaces, mostly of late-Pleistocene or Holocene age. Some of the soils, in areas of very high precipitation, formed in older deposits. Most of the soils had or now have forest vegetation, but some support shrubs or grasses. A few formed from Mollisols by human-induced erosion of the mollic epipedon, mostly from cultivation. Most of the soils have an ochric (typically thin and/or light-colored) or umbric (humus-rich with low base saturation) epipedon and a cambic (minimal soil development) subsoil horizon. A few have a mollic (rich in humus and bases) epipedon. Some also have a sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon, a fragipan (firm and brittle but not cemented layer), or a duripan (layer cemented by silica). The Udepts in the United States are most extensive in the Appalachian Mountains, on the Allegheny Plateau, and on the West Coast.



Profile of a Udept (specifically a Dystrudept) in North Carolina. Bedrock is below a depth of about 18 inches. Scale is in inches. (Photo courtesy of John Kelley)

(Back to Udepts)

Key to Great Groups of Udepts (Back to key to suborders)

Udepts that have:

1. **A sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon within a depth of 50 cm ---------------------------- Sulfudepts**
   Begin measuring depth below any O horizon.

2. **A cemented horizon within a depth of 100 cm ----------------- Durudepts**
   Begin measuring depth below any O horizon.

3. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm --- Fragiudepts**
   Begin measuring depth below any O horizon.

4. **A thick, dark-colored, humus-rich, surface horizon --------- Humudepts**
   These soils have an umbric (humus-rich with low base saturation) or mollic (rich in humus and bases) epipedon.

5. **Base saturation of $\geq$ 60% in the upper 75 cm OR free carbonates throughout the soil -- Eutrudepts**
   Base saturation is determined by NH_4OAc lab method. Begin measuring depth below any O horizon. Free carbonates will effervesce with dilute HCl.

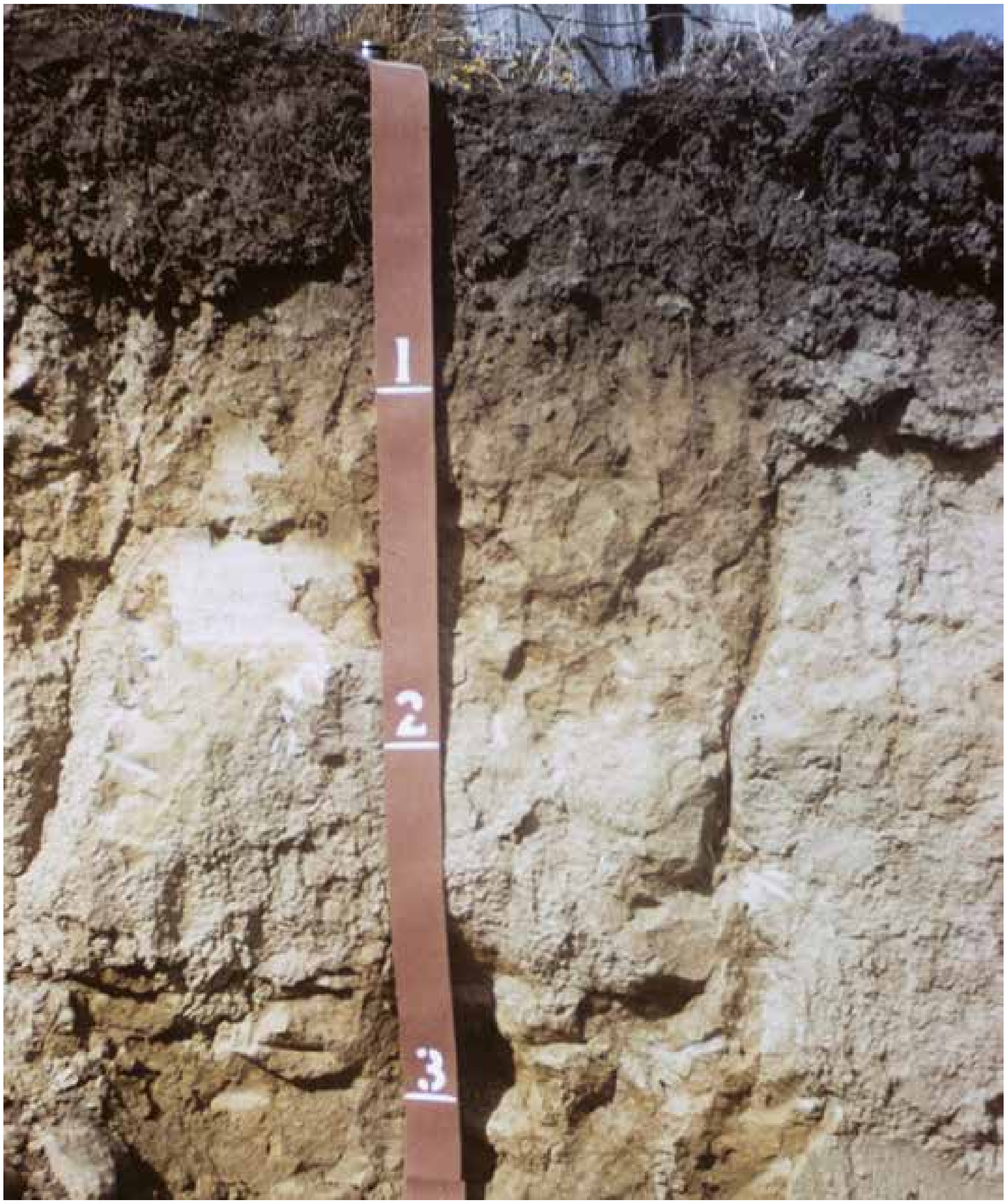
6. **Base saturation of $\leq$ 60% in the upper 75 cm AND a lack of free carbonates within a depth of 200 cm --------------------------- Dystrudepts**
   Base saturation is determined by NH_4OAc lab method. Begin measuring depth below any O horizon. Free carbonates will effervesce with dilute HCl.

Descriptions of Great Groups of Udepts

Sulfudepts—These are extremely acid soils that formed in sulfidic materials (acid-producing, oxidizable sulfur compounds) that have been exposed to oxygen, mainly as a result of surface mining, road construction, dredging, or other earthmoving operations. This exposure to oxygen resulted in the formation of a sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon. These soils are of small extent in the United States. (Back to Udepts key)

Durudepts—These soils have a duripan (layer cemented by silica) that has its upper boundary within a depth of 100 cm. Most occur in areas that generally have a Mediterranean-type climate, but they are in localized areas that have higher amounts of precipitation. Commonly, these soils have a perched water table above the duripan for part of winter or early spring. The vegetation commonly is coniferous forest. Durudepts are of very small extent in the United States. (Back to Udepts key)

Fragiudepts—These soils have a fragipan (firm and brittle but not cemented layer) within a depth of 100 cm. Commonly, they have a brownish cambic (minimal soil development) subsoil horizon that is underlain, at a depth of about 50 cm, by the fragipan. Most Fragiudepts have perched water above the pan at some time of the year, and few roots penetrate the pan. Consequently, plants on these soils tend to have shallow root systems. Many Fragiudepts formed in late-Pleistocene or Holocene deposits on gentle or moderate slopes. Some are strongly sloping. The parent materials of most Fragiudepts are loamy and either are acid or have only a small amount of free carbonates. A few of the materials are sandy and have an appreciable amount of fine sand and very fine sand. Most of the Fragiudepts in the United States are in the northeastern States and the States bordering the Mississippi and Ohio Rivers. A few are in the northern Lake States, and some are in the humid parts of the northwestern States. Fragiudepts are extensive. (Back to Udepts key)



Profile of a Fragiudept in New Zealand. This soil has an ochric epipedon about 10 inches thick underlain by a brownish yellow cambic horizon that extends to a depth of about 18 inches. A firm, dense fragipan is between depths of about 18 and 40 inches. It has prismatic structure and gray silt coatings on prism faces. Scale is in feet.

Return to Fragiudepts

Humudepts—These soils have a mollic (rich in humus and bases) or umbric (humus-rich with low base saturation) epipedon. They formed in a variety of parent materials, including residuum, colluvium, alluvium, and marine sediments. Some have an influence from volcanic ash. Most Humudepts have an ochric (typically thin and/or light-colored) epipedon and a cambic (minimal soil development) subsoil horizon. A few have root-restrictive bedrock within the profile. Most are under forest vegetation, but some support grasses or are used for pasture or cropland. In the United States, Humudepts are dominantly found near the California coast, in the Pacific Northwest, and at the higher elevations of the southern Appalachian Mountains in the East. (Back to Udepts key)

Profile of a Humudept in South Korea. This soil has an umbric epipedon about 30 cm thick. Below this epipedon is a cambic horizon that extends beyond the base of the photo. Scale colors are in 10-cm increments.

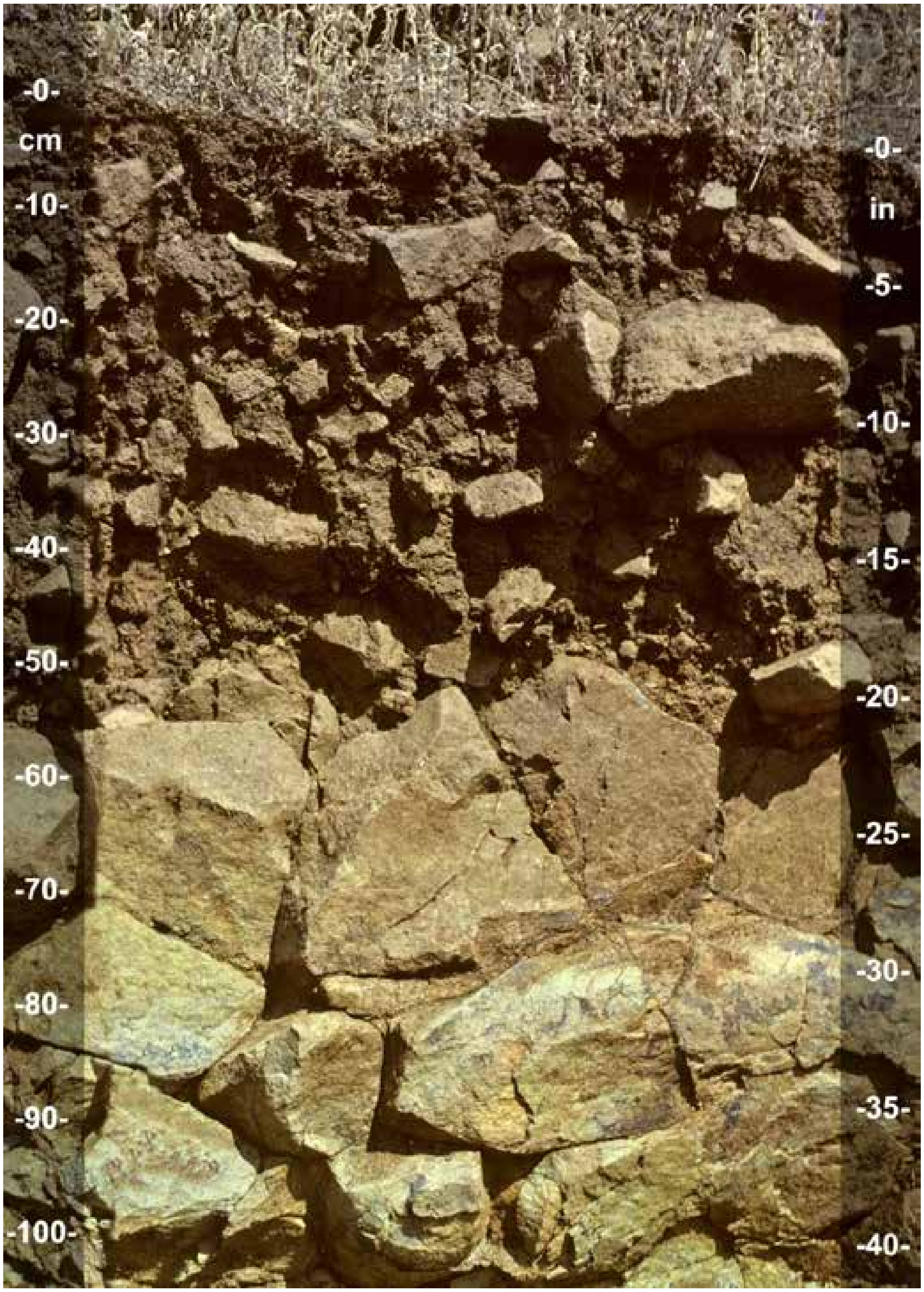
Return to Humudepts

Eutrudepts—These are the base-rich, naturally fertile soils of humid regions. Many developed in Holocene or late-Pleistocene deposits. Some of the soils with steep slopes formed in older deposits. Parent materials commonly are calcareous sediments or basic sedimentary rocks. The vegetation was mostly deciduous hardwoods, but the gently sloping soils are now cultivated and many of the steeply sloping soils are used as pasture. Eutrudepts are not extensive in the United States. (Back to Udepts key)

Profile of a Eutrudept that is shallow to limestone bedrock. It has a fairly thick dark brown ochric epipedon over a yellowish brown cambic horizon. The boundary between the soil and the underlying gray bedrock is wavy.

Return to Eutrudepts

Dystrudepts—These are the acid soils of humid regions and generally are low in natural fertility. They developed mostly in late-Pleistocene or Holocene deposits. Some developed on older, steeply sloping surfaces. The parent materials generally are acid, moderately or weakly consolidated sedimentary or metamorphic rocks or acid sediments. A few of the soils formed in saprolite derived from igneous rocks. The vegetation was mostly deciduous trees. Most of the Dystrudepts that formed in alluvium are now cultivated, and many of the other Dystrudepts are used as pasture. The typical horizon sequence in Dystrudepts is an ochric (typically thin and/or light-colored) epipedon over a cambic (minimal soil development) subsoil horizon. Some of the steeper Dystrudepts have a shallow, root-restrictive contact with bedrock or other compact, dense material. Dystrudepts are extensive in the United States and occur mostly in the eastern and southern States. (Back to Udepts key)



Profile of a very cobbly Dystrudept that formed in colluvium over weathered bedrock. This profile has an ochric epipedon about 10 cm thick underlain by a cambic horizon that extends to about 50 cm. The upper 50 cm of the soil has abundant gravel and cobbles. Below a depth of 50 cm, the material is essentially interlocking stones and boulders grading to continuous bedrock. (Photo courtesy of John Kelley)

Return to Dystrudepts

Mollisols Order

Mollisols are very dark-colored, naturally very fertile soils of grasslands.

General Characteristics

Mollisols are soils with a thick, friable, very dark-colored, organic-rich surface layer (mollic epipedon). In addition, they are naturally very fertile, having high base saturation throughout the profile. Depending on their environmental setting, Mollisols, especially those on older, relatively stable geomorphic surfaces, may have a variety of subsoil horizons. In relatively dry areas where leaching is not intense, calcic (calcium carbonate accumulation) horizons, petrocalcic (cemented by calcium carbonate) horizons, and duripans (layers cemented by silica) are known to occur. In more humid environments, argillic (clay accumulation) and natric (high levels of illuvial clay and sodium) horizons commonly occur. A few Mollisols in wet areas have a light-colored, leached albic horizon.

Environment and Processes

Mollisols formed predominantly grasslands in temperate regions at mid-latitudes in many parts of the world. To a lesser degree, they can be found in the Tropics or at high latitudes or high mountain elevations. Mollisols formed as the result of deep inputs of organic matter and nutrients from decaying roots, especially the short, mid, and tall grasses common to prairie and steppe areas (where there are high, below-ground biomass production and deep cycling of nutrients). Less commonly, Mollisols formed under forest vegetation, commonly from calcareous parent materials. Also contributing to the deep inputs and cycling of organic matter and nutrients is the activity of microbes, earthworms, ants, rodents, and other organisms.

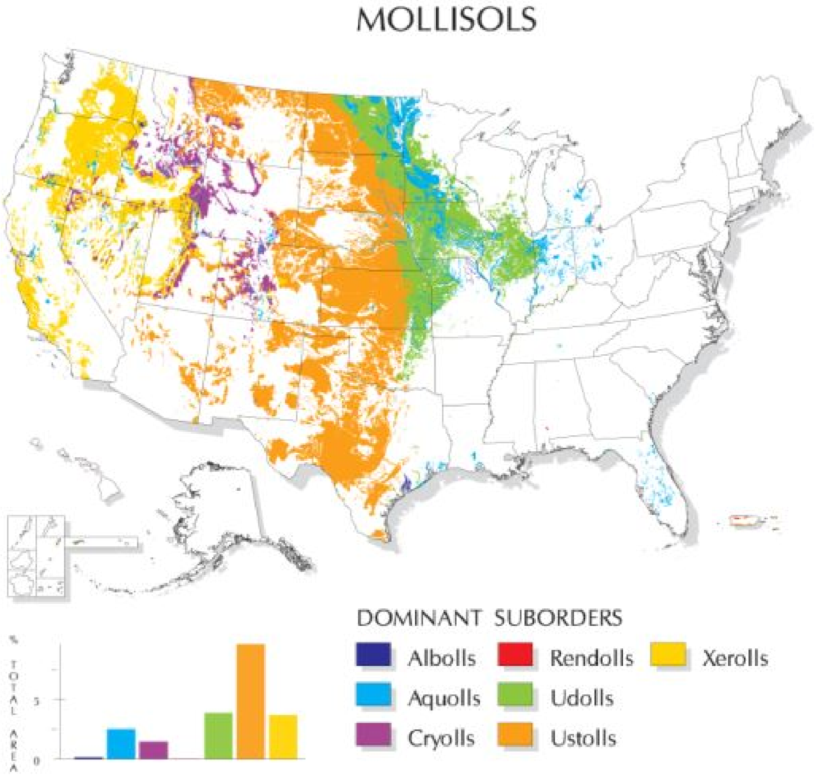
In addition to accumulations of organic matter, Mollisols have high contents of base nutrients distributed throughout their profile, making them naturally highly fertile. This is generally because Mollisols formed from mostly non-acid parent materials, which supplied bases to the soil as they weathered, and in environments (subhumid to semiarid) where the soil was not subject to intense leaching of nutrients.

Location

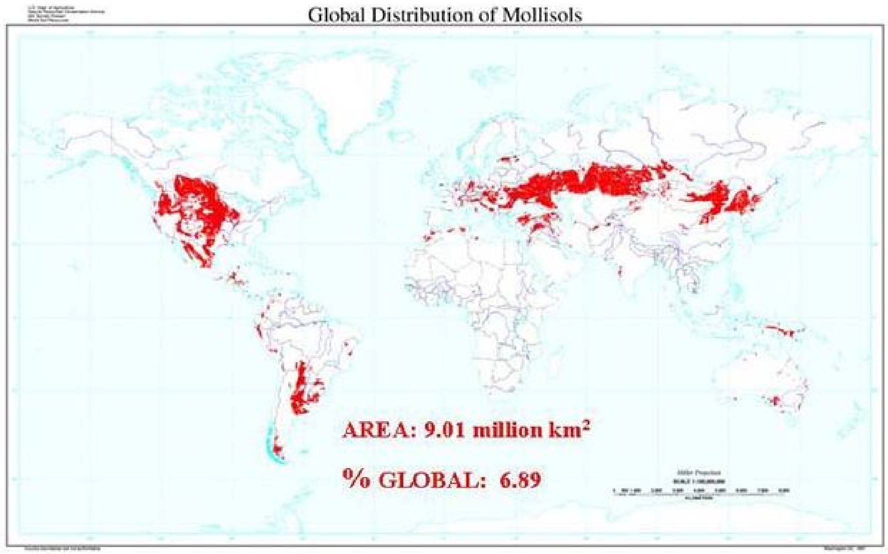
Globally, Mollisols occupy about 7% of the ice-free land area. They are commonly located between the Aridisols of very dry areas and the Alfisols and Spodosols of more humid environments. In the United States and Canada, they are common throughout the Great Plains and Prairie regions. Worldwide, they are common in the subhumid to semiarid prairie and steppe regions of Europe, Asia, and South America.

Profile of a Mollisol (specifically a Calciustoll).

(Back to Key to Soil Orders)



Mollisols by suborder in the United States. Note: This map was produced before the introduction of the Gelolls suborder. Some areas shown as Cryolls in Alaska are now Gelolls.



Global distribution of Mollisols.

Mollisols Suborders

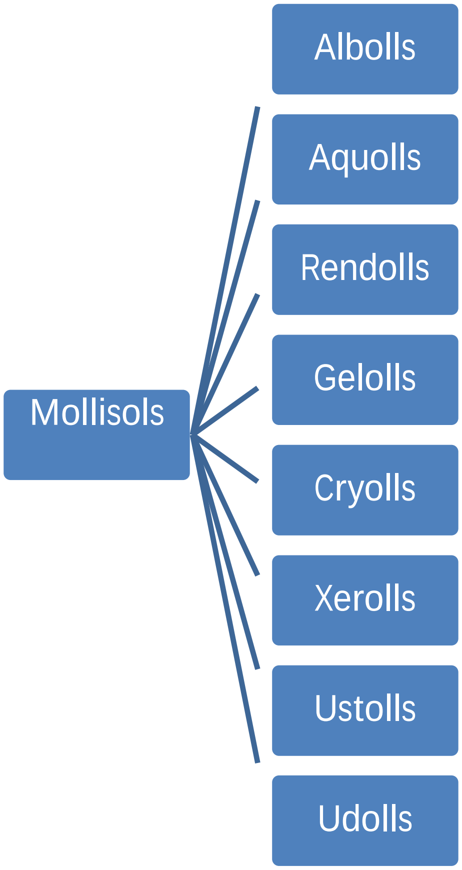
Classification of Mollisols

In the definitions of the suborders, emphasis is divided between the presence of a light-colored leached layer (albic horizon) with a fluctuating water table (Albolls), soil wetness (Aquolls), highly calcareous parent materials (Rendolls), cold soil temperature (Gelolls and Cryolls), and soil moisture regime (Xerolls, Ustolls, and Udolls).

The great groups reflect a combination of important soil properties, including the presence of various diagnostic horizons in addition to the mollic epipedon, cold soil temperature, patterns of soil saturation, intense bioturbation from earthworms or other organisms, and a morphology that reflects strong soil development on stable landforms.

The eight suborders are:

1. Albolls—Mollisols with a fluctuating water table and a light-colored zone of leaching (albic horizon)
2. Aquolls—wet Mollisols (aquic conditions in upper part)
3. Rendolls—Mollisols that formed in highly calcareous parent materials
4. Gelolls—very cold Mollisols that lack permafrost (gelic temperature regime)
5. Cryolls—cold Mollisols (cryic temperature regime)
6. Xerolls—moderately dry Mollisols (limited moisture that is supplied in winter and Mediterranean-type climate)
7. Ustolls—moderately dry Mollisols (limited moisture)
8. Udolls—Mollisols of humid regions with well-distributed rainfall


Mollisols
Albolls
Aquolls
Rendolls
Gelolls
Cryolls
Xerolls
Ustolls
Udolls

Keys to Suborders of Mollisols

Mollisols that have:

1. **A seasonal high water table within a depth of 100 cm, a light-colored leached layer (albic horizon), and an argillic (clay accumulation) or natric (high levels of illuvial clay and sodium) horizon ----------- Albolls**
   See 12th edition of "Keys to Soil Taxonomy" for specific requirements for color, thickness, and location of the albic horizon. Artificially drained soils are included in Albolls. Redoximorphic features are evidence of a seasonal high water table. Albolls have a soil temperature regime warmer than cryic.

2. **A seasonal high water table within a depth of 50 cm ------------- Aquolls**
   Redoximorphic features are evidence of a seasonal high water table. However, the intense accumulation of organic matter results in very dark colors that commonly mask the morphology of reddish and grayish colors associated with redoximorphic features. Artificially drained soils are included in Aquolls. See 12th edition of "Keys to Soil Taxonomy" for specific requirements regarding color.

3. **A calcium carbonate equivalent of $\geq$ 40% --------------------------- Rendolls**
   These soils do not have an argillic or calcic subsoil horizon. They have a udic soil moisture regime or a cryic soil temperature regime. The mollic epipedon is < 50 cm thick.

4. **Very cold average soil temperature ------------------------------------- Gelolls**
   These soils have a gelic soil temperature regime, but no permafrost.

5. **Cold average soil temperature --- Cryolls**
   These soils have a cryic soil temperature regime.

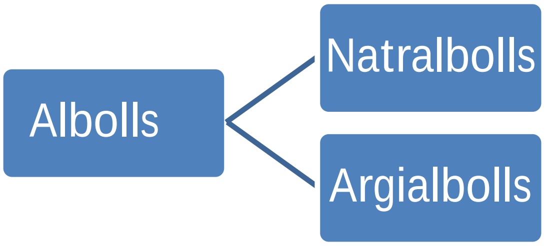
6. **A Mediterranean-type climate --- Xerolls**
   These soils typically have a xeric soil moisture regime (cool and moist in winter and warm and dry in summer). Some have an aridic soil moisture regime that borders on xeric.

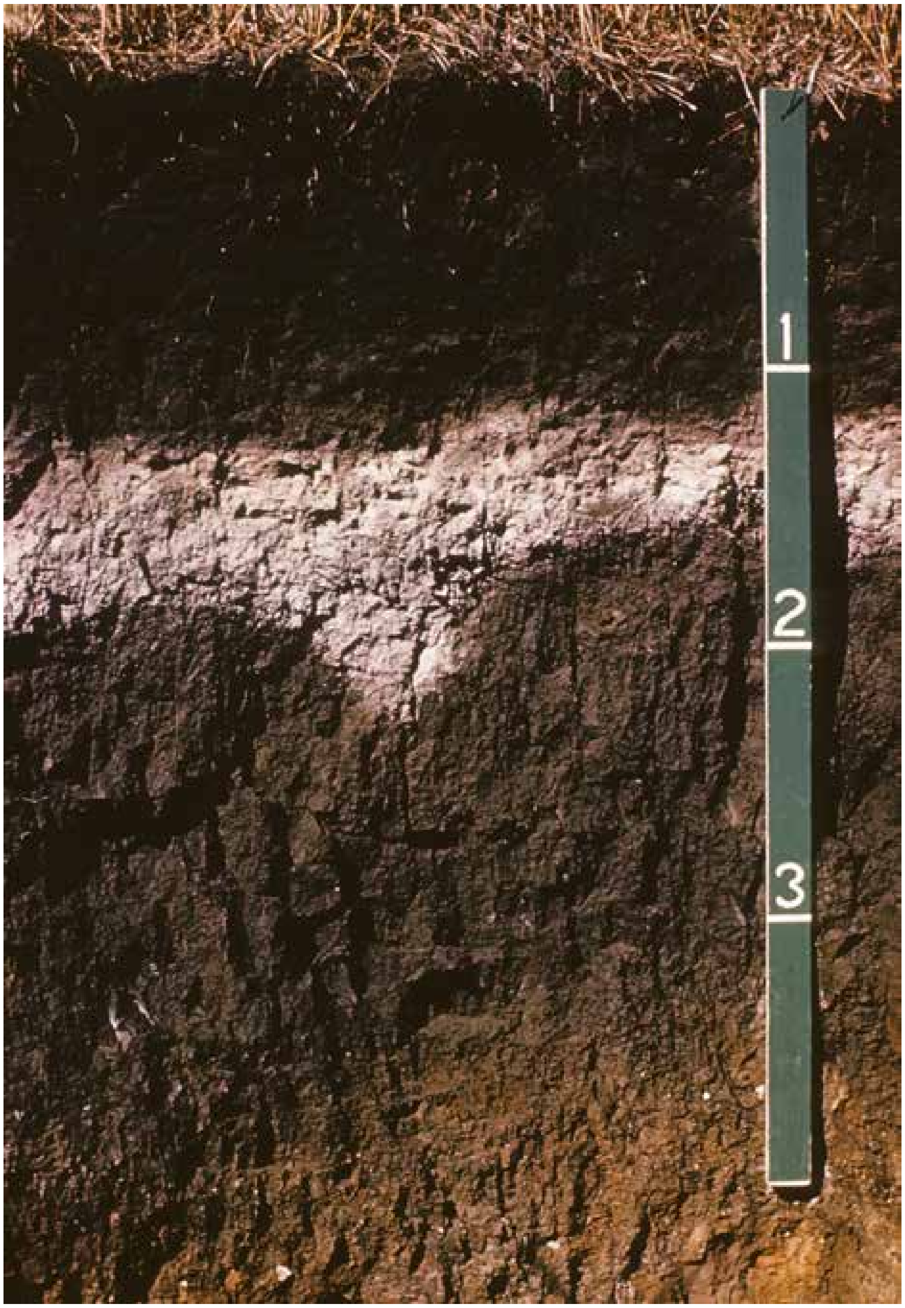
7. **Somewhat limited soil moisture available for crop growth ------ Ustolls**
   These soils typically have an ustic soil moisture regime. Moisture is limited, but available, during portions of the growing season. Some have an aridic soil moisture regime that borders on ustic.

8. **Seasonally well-distributed precipitation ------------------------------ Udolls**
   These soils have a udic soil moisture regime.

Albolls Great Groups

Albolls are the Mollisols that have an albic (light-colored and leached) horizon and fluctuating ground water levels. Most of these soils are saturated with water at or near the soil surface at some time during winter or spring in most years. In summer, ground water commonly is not within a depth of 200 cm. Below the albic horizon, there is either an argillic (clay accumulation) or natric (high levels of illuvial clay and sodium) subsoil horizon. These soils developed mostly on broad, nearly level to sloping ridges, on back slopes, or in closed depressions. Most have episaturation (perched water table). Leaching is a significant process in Albolls due to the relatively large amounts of water moving through the profile. In the United States, most Albolls are in areas of late-Pleistocene deposits. Most Albolls developed under grass or under grass and shrub vegetation. Some Albolls are thought to have had forest vegetation that was replaced by grass in the early stages of soil development. Because they have gentle slopes, most of the Albolls in the United States are now cultivated.





Profile of an Alboll (specifically an Argialboll) in China. The mollic epipedon, which extends from the surface to a depth of more than 3 feet, is separated by the intervening albic horizon (light gray). Scale is in feet.

Return to Albolls

Key to Great Groups of Albolls (Back to key to suborders)

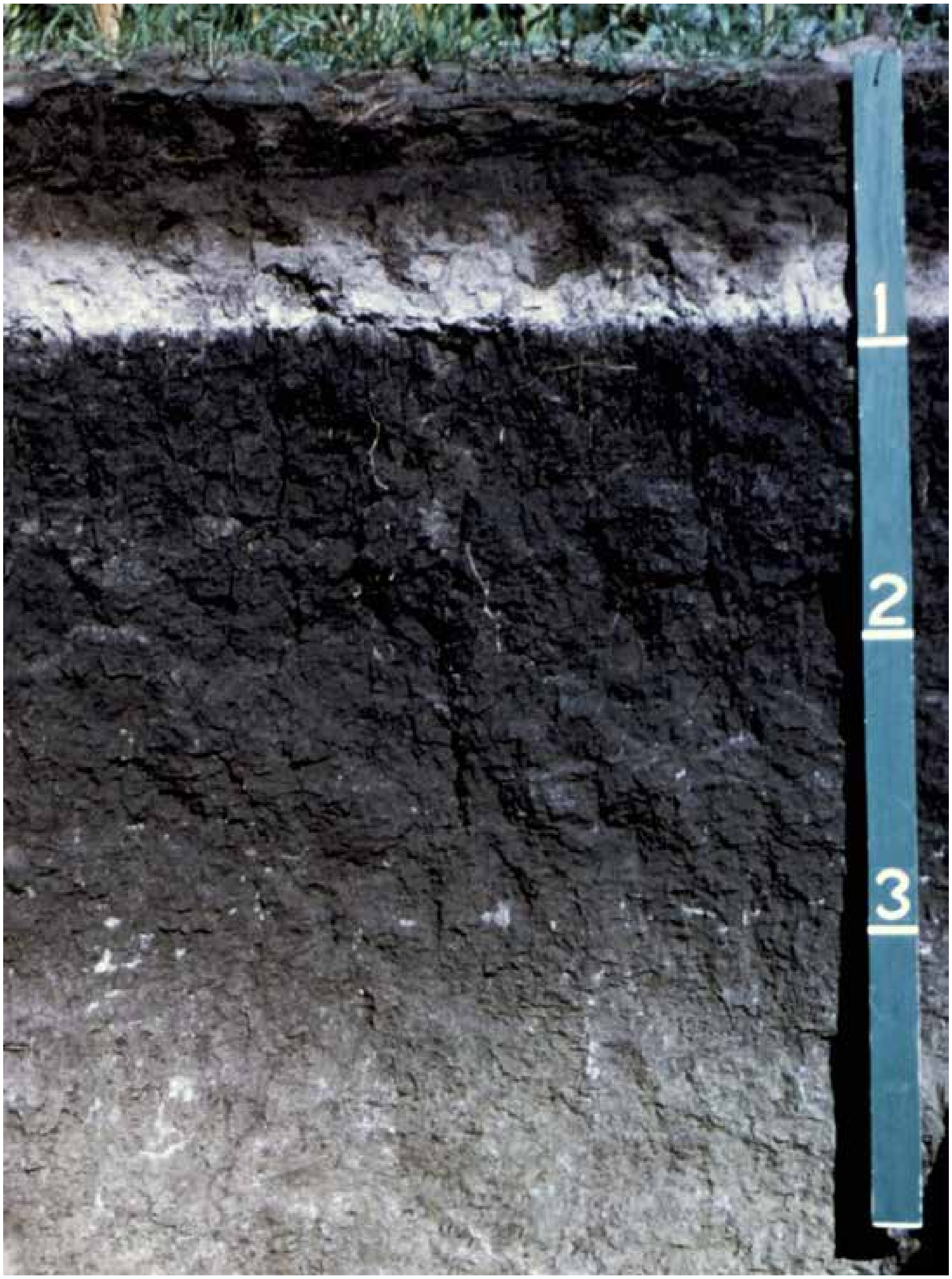
Albolls that have:

1. **A natric (high levels of illuvial clay and sodium) horizon -- Natralbolls**
2. **An argillic (clay accumulation) horizon --------------------------- Argialbolls**

Descriptions of Great Groups of Albolls

Natralbolls—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon. The natric horizon typically lies very close to the surface. These soils commonly have a thin dark surface layer overlying the light-colored, leached albic horizon. The color of the upper part of the soil, after mixing to a depth of 18 cm, however, is dark enough for a mollic epipedon because both the epipedon and the natric horizon are dark colored. Ground water is shallow during part of the year, and capillary rise in many of the soils has concentrated salts, including sodium salts, in the upper 50 cm of the profile. Natralbolls are known to occur only in subhumid and humid regions. They are in areas of late-Pleistocene till plains and lacustrine deposits or Holocene deposits. The vegetation consists of grasses and sedges. These soils are used as cropland or rangeland or for grasses cut for hay. (Back to Albolls key)

Argialbolls—These soils have an argillic (clay accumulation) subsoil horizon. Most of the soils have very dark gray to black coatings of humus and clay on the peds in the upper part of the argillic horizon. In the United States, these soils are most extensive in the loess-covered areas of the Midwestern States where the temperature regime is mesic. A very few of the soils have a frigid or thermic temperature regime. A distinct moisture deficiency in summer and a moisture surplus in winter and spring seem to be essential to the genesis of these soils. Argialbolls are associated on the landscape with all other suborders of Mollisols, except possibly Rendolls. Because they have gentle slopes, most of the Argialbolls in the United States are cultivated. (Back to Albolls key)

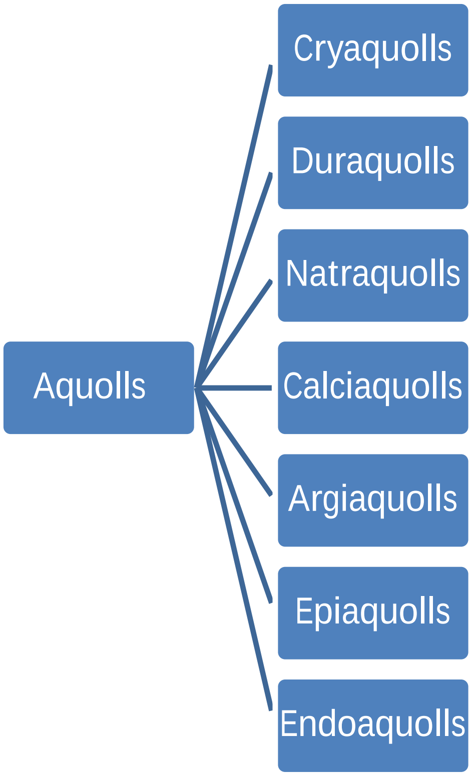


Profile of a very deep, loamy Argialboll in Kansas. This soil has a thick, dark, mollic epipedon to a depth of about 3 feet. Within this layer is a gray albic horizon about 4 to 6 inches thick from which clay has been leached. An argillic horizon begins in the lower part of the mollic epipedon and extends beyond the base of the photo. Scale is in feet.

Return to Argialbolls

Aquolls Great Groups

Aquolls are the wet Mollisols. They have color dominated by low chroma, commonly in olive hues, and have high-contrast redoximorphic depletions in or below the epipedon. These soils commonly develop in low areas where water collects and stands, but some are on broad flats or on seepy hillsides. Most of the soils have had a vegetation of grasses, sedges, and forbs, but a few also have had forest vegetation. In the United States, Aquolls are most extensive in glaciated areas of the Midwestern States where the drift or loess was calcareous. Aquolls are saturated long enough to allow oxygen- depleted conditions to develop within the upper 50 cm (aquic conditions), or they are artificially drained.



Profile of an Aquoll (specifically an Endoaquoll) in Missouri. Scale is in feet.

Return to Aquolls

Key to Great Groups of Aquolls (Back to key to suborders)

Aquolls that have:

1. **Cold average soil temperature -------------------------------------- Cryaquolls**
   These soils have a cryic soil temperature regime.

2. **A duripan (layer cemented by silica) within a depth of 100 cm -- Duraquolls**
   Begin measuring depth below any O horizon.

3. **A natric (high levels of illuvial clay and sodium) horizon --- Natraquolls**

4. **A calcic (calcium carbonate accumulation) or gypsic (gypsum accumulation) horizon within a depth of 40 cm -------------- Calciaquolls**
   Begin measuring depth below any O horizon. These soils do not have an argillic horizon, except where it occurs in a buried soil.

5. **An argillic (clay accumulation) horizon ------------------------- Argiaquolls**

6. **Episaturation (perched water table) -------------------------------- Epiaquolls**

7. **Endosaturation (saturated throughout the profile) --------- Endoaquolls**

Descriptions of Great Groups of Aquolls

Cryaquolls—These are the cold Aquolls of high elevations or high latitudes. Because they are both wet and cold, most of these soils are not cultivated. Cryaquolls may have an argillic (clay accumulation) or cambic (minimal soil development) subsoil horizon or a shallow calcic (calcium carbonate accumulation) subsoil horizon. In the United States, these soils are mostly in high mountain valleys in the West, but they are not extensive. They are used mostly for grazing or for grasses cut for hay. (Back to Aquolls key)

Duraquolls—These soils have a duripan (layer cemented by silica). In the United States, these soils are restricted to areas that have a Mediterranean-type climate or to arid regions. They are wet in winter, but most are relatively dry in summer. All Duraquolls are near enough to volcanoes to have received ash falls. The upper boundary of the duripan most commonly is about 50 to 75 cm below the soil surface. These soils range from slightly acid to strongly alkaline. They are of small extent. (Back to Aquolls key)

Natraquolls—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon that typically lies very close to the surface. The thin overlying horizon commonly has a dry color that is too light for a mollic epipedon. The color of the upper part of the soil, after mixing to a depth of 18 cm, however, is dark enough for a mollic epipedon because the natric horizon is nearly black. Ground water is shallow during most of the year, and capillary rise in many Natraquolls has concentrated salts, including sodium salts, in the upper 50 cm. Natraquolls are known to occur only in subhumid to arid regions. They are on flood plains and on the margins of lakes. They formed in late-Pleistocene or Holocene deposits. The vegetation consists of grasses, sedges, and shrubs. The soils are used as rangeland or for grasses cut for hay. They are rarely cultivated. Natraquolls are rare in the United States.
(Back to Aquolls key)

Calciaquolls—These soils have a shallow calcic (calcium carbonate accumulation) or gypsic (gypsum accumulation) subsoil horizon. Capillary rise of calcium-rich water and the subsequent evapotranspiration were important processes in the genesis of these soils. In the humid parts of the United States, these soils commonly formed around the margins of shallow, intermittent ponds in closed depressions left by glaciers. In semiarid and arid areas, they are mainly on flood plains, low terraces, and the margins of Pleistocene lakes where ground water is shallow. A calcic horizon typically is at or very close to the soil surface. Carbonates in high concentrations act as a white pigment, and not all Calciaquolls have a surface horizon that is dark colored when dry. Aquolls with a gypsic horizon are included in Calciaquolls, but no Calciaquolls with a gypsic horizon have been recognized in the United States. Calciaquolls are moderately extensive in the United States. Most are calcareous from the surface downward, and problems with plant chlorosis are common. In humid regions, potassium deficiency in plants can be severe. In arid regions, salinity may be a problem. (Back to Aquolls key)

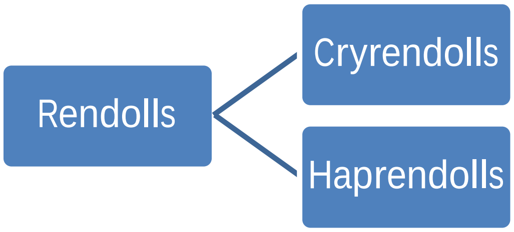
Argiaquolls—These soils have an argillic (clay accumulation) subsoil horizon. The depth to ground water in these soils fluctuates appreciably and is commonly shallow in winter and spring but deep in summer. Most of the Argiaquolls in the United States have been drained and are used as cropland. They are extensive and widely distributed throughout the Midwest and the western parts of the country. (Back to Aquolls key)

Epiaquolls—These soils have episaturation. A perched water table is at or near the soil surface during wet periods (mostly in winter and early spring) but commonly does not occur during dry periods (in summer). The depth to ground water fluctuates appreciably. Most of the Epiaquolls in the United States have some artificial drainage, mostly surface drainage, and are used as cropland. The soils are extensive and widely distributed throughout the Midwest and the western parts of the country. (Back to Aquolls key)

Endoaquolls—These soils have endosaturation. They are saturated throughout the profile at some time. The depth to ground water fluctuates appreciably. Commonly, the ground water is at or near the soil surface in winter and spring but is deep in summer. Most of the Endoaquolls in the United States have been artificially drained and are used as cropland. They are extensive and widely distributed throughout the Midwest and the western parts of the country. (Back to Aquolls key)

Rendolls Great Groups

Rendolls are the Mollisols of humid regions that formed in highly calcareous parent materials, such as limestone, chalk, drift composed mainly of limestone, or shell bars. These soils have a mollic (rich in humus and bases) epipedon that is less than 50 cm thick and that rests on the calcareous parent materials or on a cambic (minimal soil development) subsoil horizon that is rich in carbonates. A few of the soils are so rich in finely divided lime that the mollic epipedon is lighter in color than typical but is nevertheless rich in dark-colored humus and within the limits of a mollic epipedon. Rendolls are either cold (cryic soil temperature regime) or in areas with seasonally well-distributed rainfall (udic moisture regime), or both. These soils are not extensive in the United States, but they are extensive in some parts of the world, including parts of Europe and on the Mexican Yucatan peninsula. They formed under forest vegetation or under grass and shrubs.



Profile of a Rendoll (specifically a Haprendoll). The mollic epipedon rests on chalk (white). Scale is in feet.

(Back to Rendolls)

Key to Great Groups of Rendolls (Back to key to suborders)

Rendolls that have:

1. **Cold average soil temperature -------------------------------------- Cryrendolls**
   These soils have a cryic soil temperature regime.

2. **Seasonally well-distributed rainfall ------------------------------- Haprendolls**
   These soils have a udic soil moisture regime.

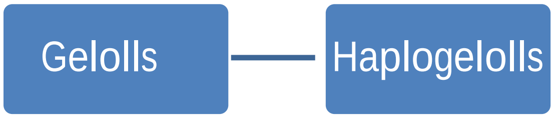
Descriptions of Great Groups of Rendolls

Cryrendolls—These soils have a cryic soil temperature regime. The Cryrendolls in the United States are rare and occur only in the mountains of the western States. The vegetation is mostly grass and shrubs. Some of the soils have widely spaced coniferous trees. (Back to Rendolls key)

Haprendolls—These soils have a udic soil moisture regime. Some have a minimally developed subsoil (cambic horizon). Haprendolls are rare in the United States. (Back to Rendolls key)

Gellols Great Groups

Gellols are the Mollisols of very cold regions. These soils have a gelic soil temperature regime but lack permafrost within the profile. They tend to be in landscape positions that are subject to wide variations in summer high temperatures and winter low temperatures, which result in mean annual soil temperatures of 0 degrees C or less, but without permafrost.



Key to Great Groups of Gelolls (Back to key to suborders)

Gelolls that have:

1. **Only a mollic epipedon or a mollic epipedon and a cambic (minimal soil development) subsoil horizon ------------------------------ Haplogelolls**

Description of the Great Group of Gelolls

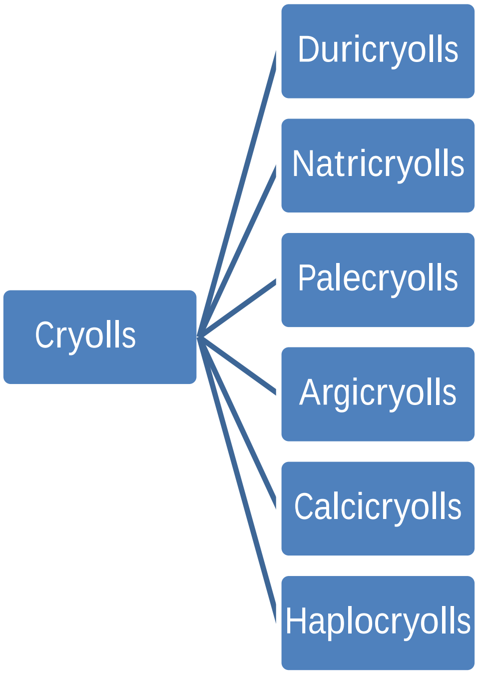
Haplogelolls—These soils are mostly well drained or excessively drained soils at high latitudes. Most have high contents of rock fragments in the profile and may also be shallow to bedrock. They commonly have a relatively thin mollic epipedon and no other diagnostic horizons, but some may have a cambic (minimal soil development) subsoil horizon. The vegetation commonly is dwarf herbaceous vegetation, coniferous forest, or alpine tundra. Haplogelolls are not extensive. In the United States, these soils occur in Alaska. (Back to Gelolls key)

Cryolls Great Groups

Cryolls are the cool or cold, more or less freely drained Mollisols. These soils have various diagnostic subsoil horizons, including a duripan (layer cemented by silica), an argillic (clay accumulation) horizon, a natric (high levels of illuvial clay and sodium) horizon, a calcic (calcium carbonate accumulation) horizon, or a cambic (minimal soil development) horizon. They are moderately extensive in the high mountains of the western United States. They also are extensive on the plains and mountains of Eastern Europe and in Asia. On the plains, they are mainly in areas of late-Pleistocene or Holocene deposits. In the mountains of the western United States, some of the soils may be on older surfaces, but the geomorphology of these areas has had little study.

Cryolls have a cryic temperature regime and a udic (seasonally well-distributed precipitation), ustic (moisture is limited, but available, during portions of the growing season), or xeric (cool and moist in winter and warm and dry in summer) moisture regime.

The vegetation of the Cryolls was mostly grasses on the plains and either forest or grass in the mountains. In Alaska, spruce, birch, and aspen trees are common on these soils.



Profile of a Cryoll (specifically a Natricryoll). The soil has a natric horizon below a depth of 14 inches. Scale is in inches.

(Back to Cryolls)

Key to Great Groups of Cryolls (Back to key to suborders)

Cryolls that have:

1. **A duripan (layer cemented by silica) within a depth of 100 cm -- Duricryolls**
   Begin measuring depth below any O horizon.
2. **A natric (high levels of illuvial clay and sodium) horizon -- Natricryolls**
3. **An argillic (clay accumulation) horizon beginning deeper than 60 cm AND loamy or clayey texture above ------------------------------- Palecryolls**
   Begin measuring depth below any O horizon.
4. **An argillic (clay accumulation) horizon -------------------------- Argicryolls**
5. **A calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon within a depth of 100 cm AND free carbonates or sandy texture above ------------------------------- Calcicryolls**
   Begin measuring depth below any O horizon.
6. **A cambic (minimal soil development) or calcic (calcium carbonate accumulation) horizon -- Haplocryolls**

Descriptions of Great Groups of Cryolls

Duricryolls—These soils have a duripan (layer cemented by silica) that has its upper boundary within a depth of 100 cm. They are of small extent in the mountain valleys of the western United States. Many had grasses and widely spaced conifer trees. Most of these soils are used as rangeland or forest. (Back to Cryolls key)

Natricryolls—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon. They are rare. (Back to Cryolls key)

Palecryolls—These soils have an argillic (clay accumulation) subsoil horizon with an upper boundary more than 60 cm below the surface. Most of the Palecryolls in the United States are in the mountains of the western States. In other countries, at high latitudes, Palecryolls also developed on plains. Palecryolls have cool or short summers. Many of the soils had grasses and scattered conifer trees. In the United States, the vegetation at the time of settlement was either forest or grass. Most Palecryolls are used as rangeland or forest. Some are cultivated and used for small grain or hay. (Back to Cryolls key)

Argicryolls—These soils have an argillic (clay accumulation) subsoil horizon close to the surface. Commonly, the upper part of the argillic horizon is in the mollic epipedon. Some of these soils have calcium carbonate accumulations below the argillic horizon. Argicryolls formed mainly in Pleistocene or Holocene deposits or are on surfaces of equivalent ages. They have cool or short summers. Most Argicryolls in the United States are in the mountains of the western States. A few are in Alaska. In other countries, at high latitudes, Argicryolls also developed on plains. Many of the soils had grasses and scattered conifer trees. In the United States, the vegetation at the time of settlement was either forest or grass. Most Agricryolls are used as rangeland or forest. Some are cultivated and used for small grain or hay. (Back to Cryolls key)

Calcicryolls—These soils have a calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) subsoil horizon that has its upper boundary within a depth of 100 cm. They are calcareous, or would be calcareous if plowed, in all parts of the pedon above the calcic horizon, or they have a texture of loamy fine sand or coarser in all parts above the calcic or petrocalcic horizon. The mollic epipedon commonly includes part of the calcic horizon. These soils formed in materials that have a moderate to high percentage of carbonates. Many of the soils are in areas of deposits that originated from limestone. Calcicryolls occur in areas of cool or short summers. In the United States, the vegetation at the time of settlement was either grass or forest. The soils are of moderate extent in the mountains of the western United States. Most of the soils are used as rangeland, forest, or wildlife habitat. A few areas are cultivated and used for small grain or hay. (Back to Cryolls key)

Haplocryolls—Most Haplocryolls have a cambic subsoil horizon, and some have a calcic horizon. Haplocryolls formed mainly in Pleistocene or Holocene deposits or on surfaces of equivalent ages. They have cool or short summers. Many of the soils had grasses and scattered conifer trees. The vegetation at the time of settlement was either forest or grass. Most of the soils are used as rangeland or forest. Some are cultivated and used for small grain or hay. Haplocryolls are extensive in the United States. (Back to Cryolls key)

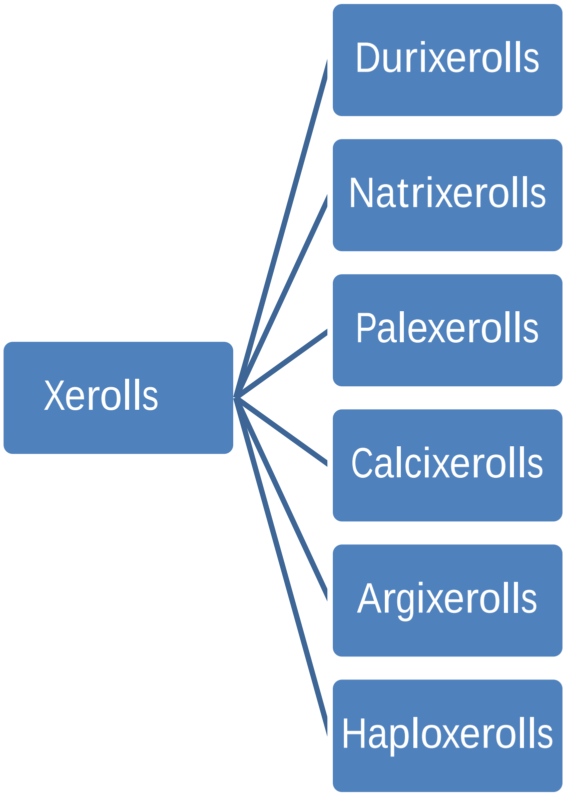
Xerolls Great Groups

Xerolls are the Mollisols in regions that have Mediterranean-type climates, characterized by cool, moist winters, and warm, dry summers. As their name implies, they generally have a xeric moisture regime. Some Xerolls that are marginal to Aridisols, however, have an aridic moisture regime. Xerolls are dry for extended periods in summer, but moisture moves through most of the soils in winter and is stored throughout the profile above the deep layers or above bedrock in most years. Soft, white winter wheat is the most common crop on the Xerolls in the United States where there is no irrigation and temperatures are moderate. In colder areas, these soils are used for spring wheat or for grazing. With irrigation, many crops are grown, especially in the warmer areas. The soils with steep slopes mainly support natural vegetation consisting of native annual or perennial grasses or of shrubs or trees. These soils are used mainly for grazing in spring or late fall. The native perennial grasses remain dormant during the dry summers, and the annual grasses grow mainly in spring and sometimes in fall, if rains occur before temperatures become too low.

Characteristically, Xerolls have a relatively thick mollic epipedon, a cambic (minimal soil development) or argillic (clay accumulation) subsoil horizon, and an accumulation of carbonates in the lower part of the subsoil. Most horizons have neutral pH.

The Xerolls in the United States formed mainly in late-Pleistocene loess that varied in thickness and that overlay bedrock on nearly level to steep older surfaces. Tertiary lake sediments, older crystalline rocks, and alluvium are common parent materials in some areas. The vegetation at the time of settlement in the areas with moderate to cold temperatures was dominantly bunchgrass and shrubs; wheatgrass (*Agropyron*), fescue (*Festuca*), and bluegrass (*Poa*) species in association with sagebrush (*Artemisia*), bitterbrush (*Purshia*), and rabbitbrush (*Chrysothamnus*) species; and some scattered juniper (*Juniperus*) and pine (*Pinus*) species. In the Willamette Valley of Oregon, the vegetation was a savanna of perennial grasses, oaks, and Douglas fir. In the warmer areas of California, the vegetation was a savanna of annual grasses and oak species.

Xerolls are not extensive worldwide, but they are extensive in parts of Turkey and northern Africa near the Mediterranean Sea, in some of the southern republics of the former Soviet Union, and in Washington, Oregon, Idaho, Utah, Nevada, and California in the United States.


Xerolls
Durixerolls
Natrixerolls
Palexerolls
Calcixerolls
Argixerolls
Haploxerolls

Profile of a Xeroll (specifically a Haploxeroll). The mollic epipedon is cobbly and rests directly on bedrock at a depth of about 2 feet. Scale is in feet.

(Back to Xerolls)

Key to Great Groups of Xerolls (Back to key to suborders)

Xerolls that have:

1. **A duripan (layer cemented by silica) within a depth of 100 cm -- Durixerolls**
   Begin measuring depth below any O horizon.

2. **A natric (high levels of illuvial clay and sodium) horizon -- Natrixerolls**

3. **Either:**

   a) **A petrocalcic (cemented by calcium carbonate) horizon within a depth of 150 cm, OR**

   b) **An argillic (clay accumulation) horizon in which the clay content does not decrease significantly within a depth of 150 cm and that has hue of 7.5YR or redder color (and there is no root-limiting layer within a depth of 150 cm), OR**

   c) **An abrupt increase in clay content to an argillic (clay accumulation) horizon with clayey texture (and no root-limiting layer within a depth of 50 cm) ---------------------------------- Palexerolls**

   Begin measuring depth below any O horizon. For item b, clay content must not decrease by ≥ 20% of the maximum in the argillic horizon. For specific criteria regarding colors and regarding an abrupt clay increase (item c), see 12th edition of "Keys to Soil Taxonomy."

4. **A calcic (calcium carbonate accumulation) or gypsic (gypsum accumulation) horizon within a depth of 150 cm AND free carbonates or sandy texture above --- Calcixerolls**
   Begin measuring depth below any O horizon.

5. **An argillic (clay accumulation) horizon -------------------------- Argixerolls**

6. **A cambic (minimal soil development) horizon or no diagnostic subsoil horizon -- Haploxerolls**

Descriptions of Great Groups of Xerolls

Durixerolls—These soils have a duripan (layer cemented by silica) that has its upper boundary within a depth of 100 cm. They formed mainly in Pleistocene sediments. In many of these soils, some of the materials near the surface are younger than the duripan. The parent materials commonly were derived, at least partially, from basic volcanic rocks, siliceous tuffs, pumice, or volcanic ash. They generally are gently sloping or moderately sloping. The natural vegetation on the Durixerolls in the United States was grass and shrubs. These soils occur in the western United States, but they are not extensive. (Back to Xerolls key)

Natrixerolls—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon. The natric horizon commonly has either prismatic or columnar structure, and there are accumulations of calcium carbonate in or below it. Some of the soils have a thin albic (light-colored and leached) horizon above the natric horizon. Natrixerolls formed mostly in mixed sediments of late-Pleistocene age, commonly in depressions, in basins, or on low terraces. Individual areas of these soils are mostly small. (Back to Xerolls key)

Palexerolls—These soils formed on old surfaces, commonly on basalt plains of Miocene or Pliocene age that later, during or after the late Pleistocene, received a thin covering of loess or of mixed loess and ash. Slopes range from nearly level to very steep. The soils commonly have a thick, dark brown or reddish brown, clayey argillic (clay accumulation) subsoil horizon that has an abrupt upper boundary, or they have a petrocalcic (cemented calcium carbonate) subsoil horizon. Calcium carbonate accumulations are common below or in the lower part of the argillic horizon. The native vegetation was mainly bunchgrasses and some shrubs. Some of the soils supported a coniferous forest with an understory of grasses and shrubs or supported an open forest or savanna. Palexerolls occur in parts of the western United States, but they are not extensive. (Back to Xerolls key)

Calcixerolls—These soils have a calcic (calcium carbonate accumulation) or gypsic (gypsum accumulation) subsoil horizon and are calcareous in all overlying horizons. Either the parent materials had more carbonates than rainfall could remove from the upper horizons, or there is a continual external source of carbonates in dust or water. Calcixerolls formed mostly in late-Pleistocene sediments or in older materials on surfaces of comparable age. Slopes range from nearly level to very steep. In the United States, their native vegetation was mostly grass and shrubs. These soils are most extensive in the Great Basin of the western United States. (Back to Xerolls key)

Argixerolls—These soils have a relatively thin argillic (clay accumulation) subsoil horizon or one in which the percentage of clay decreases rapidly with increasing depth. Generally, the mollic epipedon is very dark brown and the argillic horizon is dark brown. Most of these soils have calcium carbonate accumulations below or in the lower part of the argillic horizon. Argixerolls formed mostly in mid-Pleistocene or earlier deposits or on surfaces of Tertiary age. Slopes range from nearly level to very steep. The natural vegetation is mostly grasses and shrubs, but some of the soils support coniferous forest vegetation with a grass and shrub understory and some have an open forest or savanna. (Back to Xerolls key)

Haploxerolls—These soils are characterized by little development in the subsoil. Commonly, they have a cambic (minimal soil development) subsoil horizon below the mollic epipedon. Some have only unaltered recent parent materials below the mollic epipedon. Many have horizons in which secondary carbonates have accumulated. A few have a calcic (calcium carbonate accumulation) subsoil horizon, but at least parts of the surface horizons are free of carbonates. Haploxerolls formed mainly in late-Pleistocene deposits or on surfaces of comparable age, but some formed on older surfaces. Parent materials of late-Wisconsinan loess mixed with some volcanic ash, glacial outwash or till, and alluvium from mixed sources are common. Slopes range from nearly level to very steep. The natural vegetation is mostly grasses and shrubs, but some of the soils support a coniferous forest with a grass and shrub understory and some support an open forest or savanna. (Back to Xerolls key)

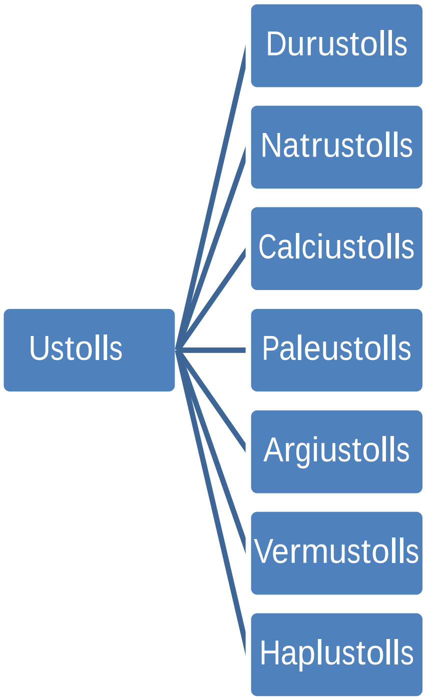
Ustolls Great Groups

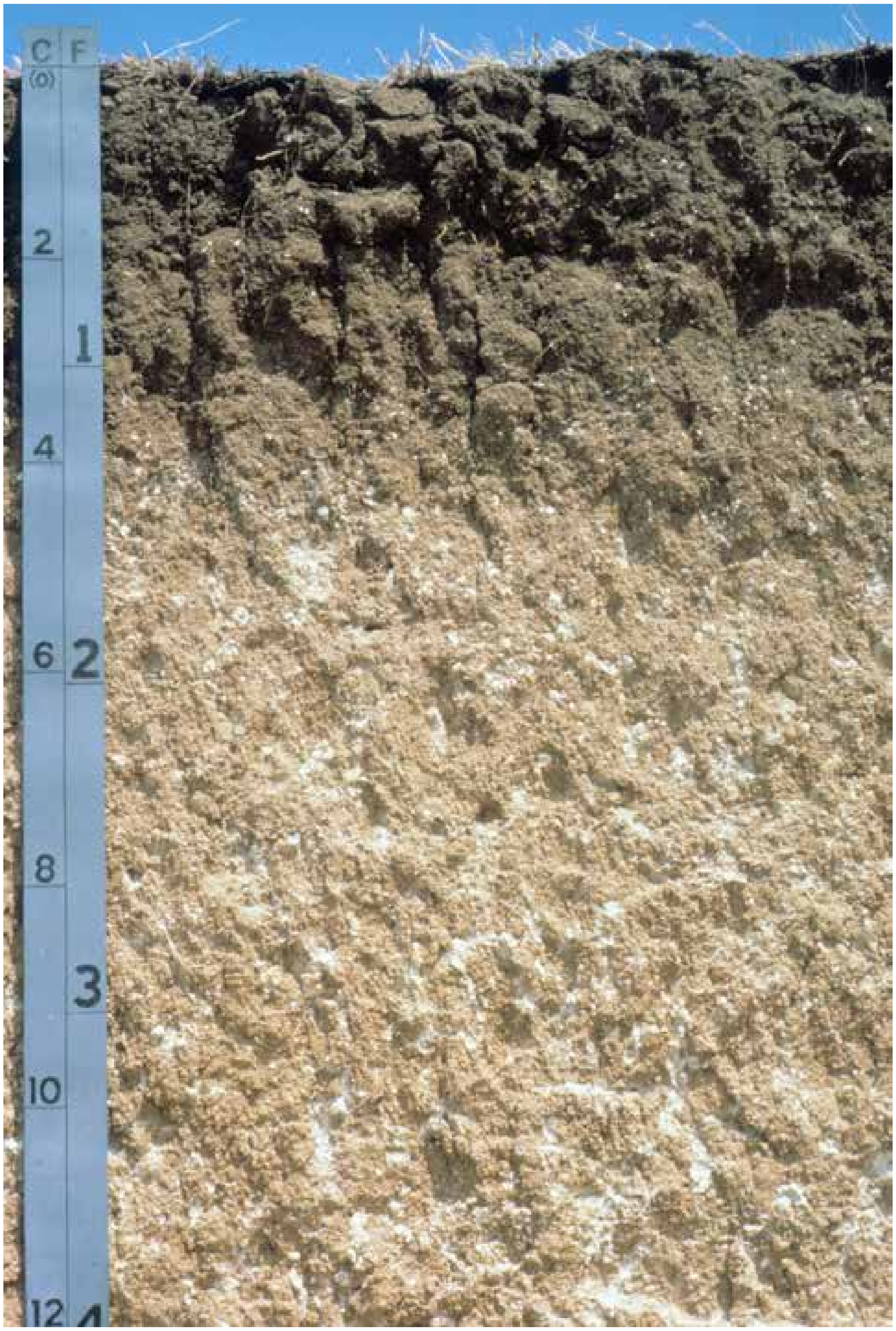
Ustolls are the more or less freely drained Mollisols of subhumid to semiarid climates. Rainfall occurs mainly during a growing season, often in heavy showers, but is erratic. Drought is frequent and may be severe. During a drought, soil blowing becomes a problem. In nonirrigated areas, the low supply of moisture usually limits crop yields. Ustolls are extensive soils on the western Great Plains in the United States.

In addition to the mollic epipedon, most Ustolls have accumulations of calcium carbonate in the subsoil; a few of the soils that formed in noncalcareous materials do not. Ustolls may also have a cambic (minimal soil development), argillic (clay accumulation), petrocalcic (cemented by calcium carbonate), or natric (high levels of illuvial clay and sodium) subsoil horizon. If there is a natric horizon, there may be an albic (light-colored and leached) horizon overlying it, or if there is a cambic or argillic horizon, there may be a duripan (layer cemented by silica) below it. The presence or absence of these horizons is used, in part, as the basis for defining the great groups of Ustolls.

Most of the Ustolls on the Great Plains in the United States had grass vegetation when the country was settled. In drier areas they supported mostly short grasses, and in more humid areas they supported mixtures of short and tall grasses. Some of the Ustolls in the mountains of the western States supported forest vegetation.

Ustolls formed in sediments and on surfaces of varying ages, ranging from Holocene to mid Pleistocene or earlier. Those outside of glaciated areas may have formed during two or more glacial and interglacial stages.





A profile of an Ustoll (specifically a Calciustoll) in Texas. The dark-colored mollic epipedon is underlain by a thick calcic horizon beginning at a depth of about 35 cm. White bodies are accumulations of calcium carbonate.

Back to Ustolls

Key to Great Groups of Ustolls (Back to key to suborders)

Ustolls that have:

1. A duripan (layer cemented by silica) within a depth of 100 cm -- Durustolls
Begin measuring depth below any O horizon.

2. A natric (high levels of illuvial clay and sodium) horizon -- Natrustolls

3. **Either:**

a) A calcic (calcium carbonate accumulation) or gypsic (gypsum accumulation) horizon within a depth of 100 cm, OR

b) A petrocalcic horizon within a depth of 150 cm,

AND

c) Free carbonates or sandy texture above -------------------- Calciustolls
Begin measuring depth below any O horizon. Calciustolls do not have an argillic horizon above any calcic, gypsic, or petrocalcic horizon.

4. Either:

a) A petrocalcic (cemented by calcium carbonate) horizon within a depth of 150 cm, OR

b) An argillic (clay accumulation) horizon in which clay does not decrease significantly within a depth of 150 cm and that has hue of 7.5YR or redder color (and there is no root-limiting layer within a depth of 150 cm), OR

c) An abrupt increase in clay content to an argillic (clay accumulation) horizon with clayey texture (and no root-limiting layer within a depth of 50 cm) ----------------------------------- Paleustolls
Begin measuring depth below any O horizon. For item b, clay content must not decrease by ≥ 20% of the maximum in the argillic horizon. For specific criteria regarding colors and regarding an abrupt clay increase (item c), see 12th edition of “Keys to Soil Taxonomy.”

5. An argillic (clay accumulation) horizon --------------------------- Argiustolls

6. **Significant evidence of bioturbation ------------------------------ Vermustolls**
   Bioturbation must be evident in ≥ 50%, by volume, of the surface layer and ≥ 25% of a transition zone to the subsoil below.

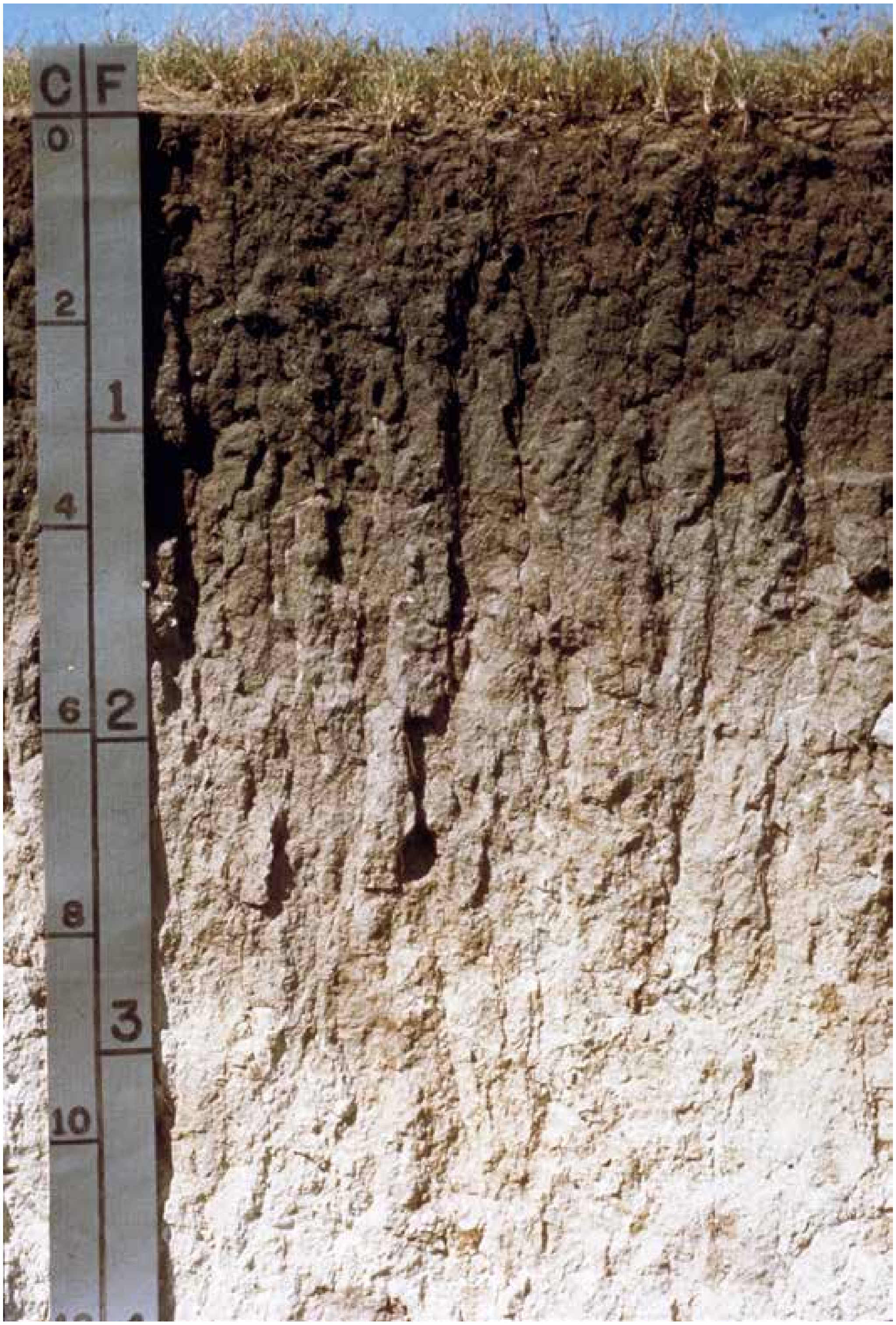
7. **A cambic (minimal soil development) horizon ----------------- Haplustolls**

Descriptions of Great Groups of Ustolls

Durustolls—These soils have a duripan (layer cemented by silica) with its upper boundary within a depth of 100 cm. They formed in the vicinity of cinders and ash falls. Their parent materials are mainly siliceous tuffs, volcanic ash, cinders, and basic volcanic rocks. In the United States, the natural vegetation is mostly grasses and shrubs. These soils are of small extent. They formed in late-Pleistocene deposits. They are on alluvial fans and terraces, on nearly level to rolling cinder fans and plains, and on hilly to very steep cinder cones. They may be common on the leeward sides of volcanic islands in the Lesser Antilles. (Back to Ustolls key)

Natrustolls—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon. The most common horizon sequence is either a natric horizon in the lower part of the mollic epipedon or a thin albic (light-colored and leached) horizon over a natric horizon with columnar structure. Calcium carbonate or other salts may have accumulated below the natric horizon. Most of the areas of these soils are small and are nearly level or concave. Natrustolls formed mostly in late-Pleistocene sediments. (Back to Ustolls key)

Calciustolls—These soils have a gypsic (gypsum accumulation), calcic (calcium carbonate accumulation), or petrocalcic (cemented by calcium carbonate) subsoil horizon and are calcareous in all overlying horizons. Either the parent materials had more carbonates than the limited rainfall could remove from the upper horizons, or there is a continual external source of carbonates in dust or water. Calciustolls formed mostly in Pleistocene sediments or in older materials on surfaces of comparable age. In the United States, their vegetation was dominantly grass before the soils were cultivated. Calciustolls are most extensive on the Great Plains in the United States, but some occur in the intermountain valleys of the western States. (Back to Ustolls key)

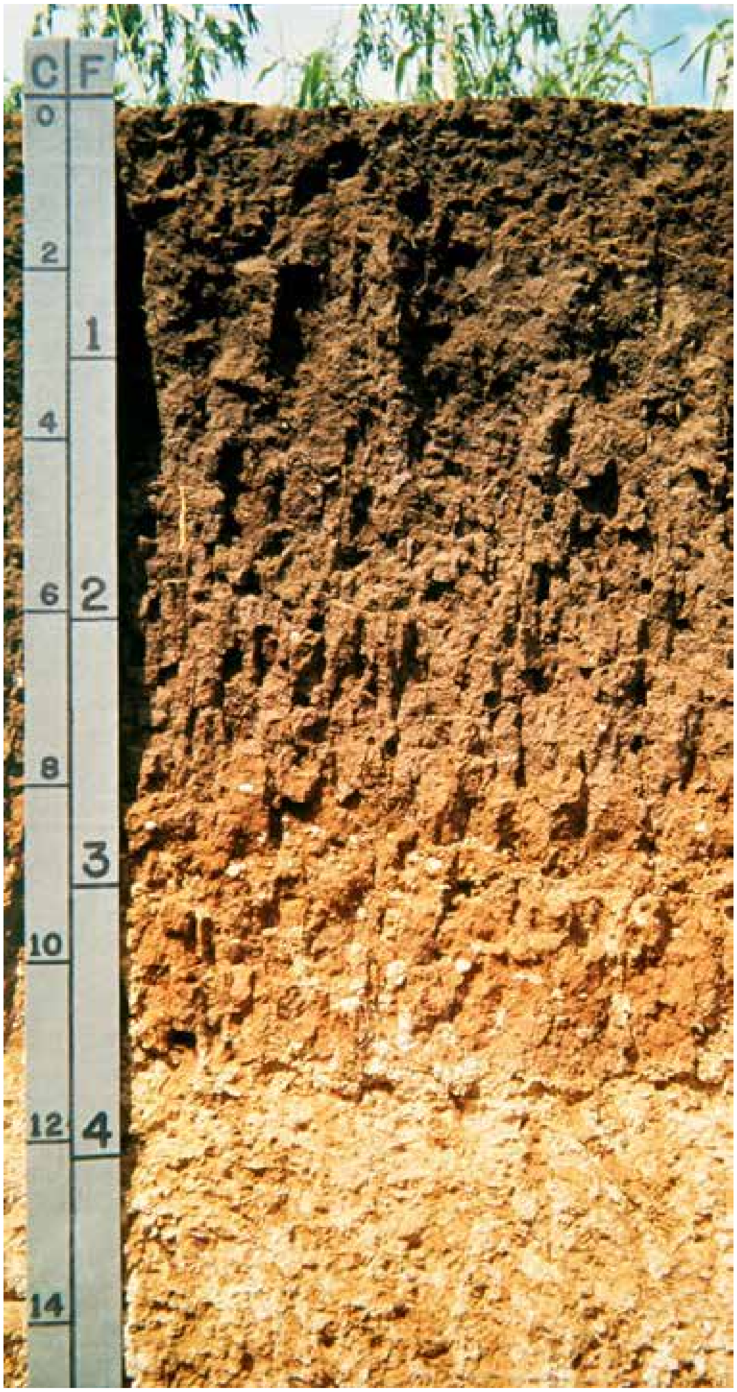


Profile of a Calciustoll in a semiarid area of Texas. It has a mollic epipedon about 45 cm thick. Below this epipedon is a light gray to white calcic horizon that extends beyond the base of the photo.

Return to Calciustolls

Paleustolls—These are the Ustolls on old stable surfaces, as evidenced by the development of a thick, reddish argillic horizon, a clayey argillic horizon that has an abrupt upper boundary, or a petrocalcic (cemented by calcium carbonate) horizon. These soils commonly have been partly or completely calcified during the Holocene, and calcium carbonate has accumulated in the previously formed argillic horizon. The Paleustolls in the United States are mainly in the central and southern parts of the Great Plains. At the time of settlement, they had mostly grass vegetation. Their history during the Pleistocene has had little study. The petrocalcic horizon, where it occurs, may be complex, suggesting a number of alternating cycles of humidity and aridity and slow accretion of dust and sediment from the arid regions to the west.

(Back to Ustolls key)



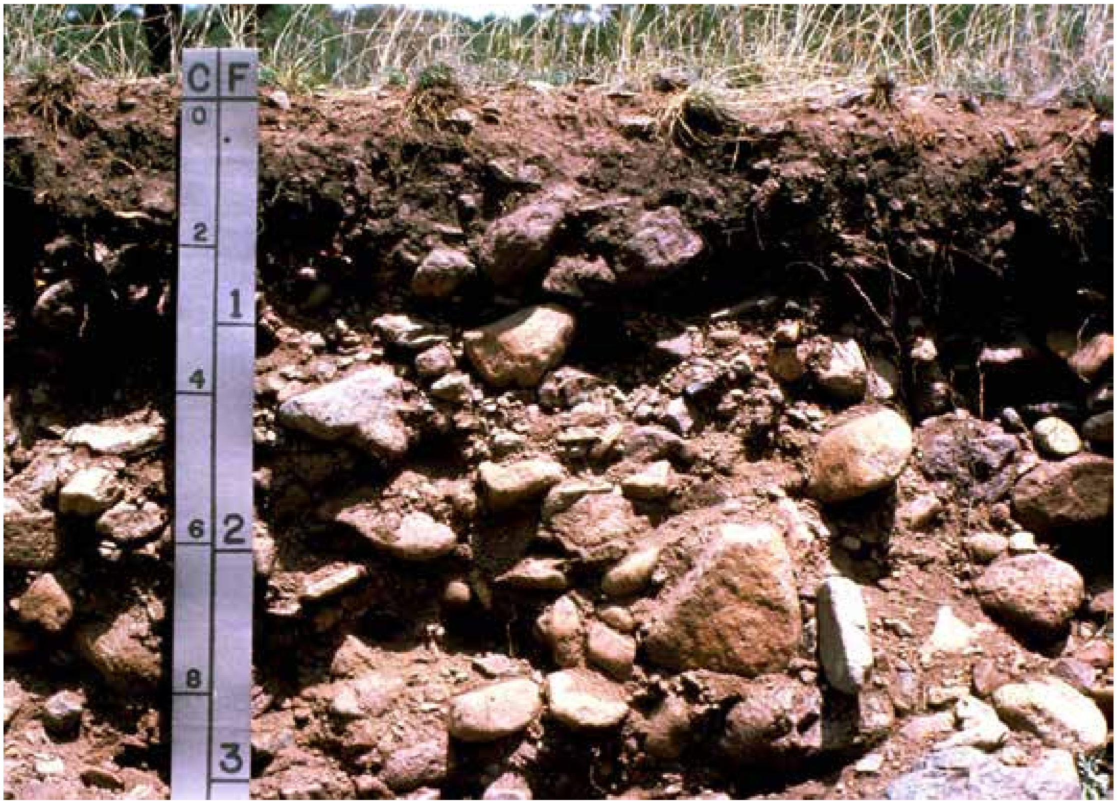
Profile of a well drained Paleustoll in a semiarid area of the southern Great Plains. It has a mollic epipedon about 26 cm thick. Below this epipdon is an argillic horizon that extends to a depth of about 110 cm. Below 110 cm is a calcic horizon. The left side of the scale is in 20-cm increments.

Return to Paleustolls

Argiustolls—These soils have an argillic (clay accumulation) subsoil horizon in or below the mollic epipedon. Most of these soils have an argillic horizon that, with increasing depth, has a clay decrease of 20% or more (relative) from the maximum clay content within 150 cm of the mineral soil surface. Some of the soils have a root-limiting layer (densic, lithic, or paralithic contact) within a depth of 150 cm, and some have no hues of 7.5YR or redder or have chroma of 4 or less. Most of these soils have a zone of accumulation of calcium carbonate or other salts below the argillic horizon. Argiustolls formed mostly in late-Pleistocene deposits or on surfaces of comparable age. They occur in relatively stable positions. Slopes generally are moderate to nearly level, and most of the soils are cultivated. Argiustolls are extensive on the western Great Plains and also occur in the mountains and valleys of the western United States. (Back to Ustolls key)

Vermustolls—These soils have been intensively and repeatedly mixed by animals, mainly by earthworms and their predators. The most common horizon sequence is a mollic epipedon consisting mostly of wormcasts that rests on parent materials that contain many worm channels filled with dark materials from the surface. There may be a horizon in which carbonates have precipitated, but mixing by animals may have destroyed such a horizon or prevented its formation. Vermustolls are not known to occur in North America, but they are extensive in Eastern Europe. (Back to Ustolls key)

Haplustolls—Most of these soils have a cambic (minimal soil development) subsoil horizon below the mollic epipedon, and most have a horizon in which carbonates or soluble salts have accumulated. A few that formed in noncalcareous sediments do not have a horizon of carbonate accumulation. Haplustolls formed mainly in late-Pleistocene or Holocene deposits or on surfaces of comparable age. Their vegetation has been dominantly grasses and forbs. These soils are extensive on the Great Plains of North America, in Eastern Europe, and on the Pampas in South America. Where slopes are suitable, most of the soils are used for grain and feed crops. (Back to Ustolls key)



Profile of a very cobbly Haplustoll in Texas. This soil has a mollic epipedon about 30 cm thick and no other diagnostic horizon. It formed in alluvial deposits containing large amounts of gravel, cobbles, and stones. Note the water-rounded shape of the rock fragments.

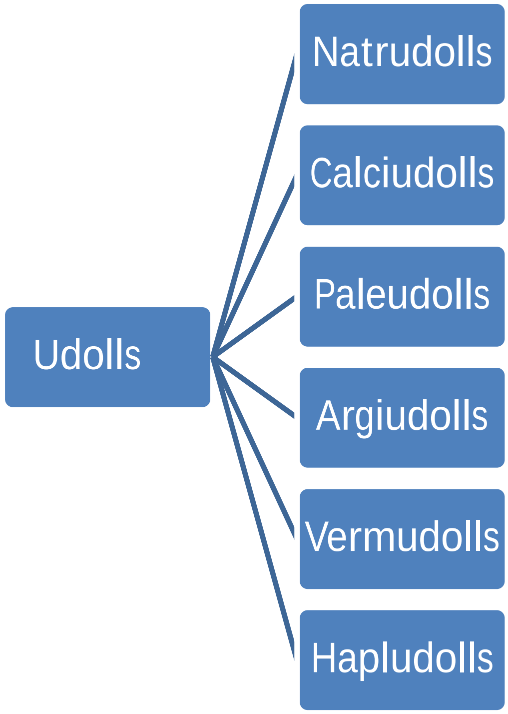
Return to Haplustolls

Udolls Great Groups

Udolls are the more or less freely drained Mollisols of humid climates. In addition to the mollic epipedon, these soils may have a cambic (minimal soil development), calcic (calcium carbonate accumulation), natric (high levels of illuvial clay and sodium), or argillic (clay accumulation) subsoil horizon. They formed mainly in late-Pleistocene or Holocene deposits or on surfaces of comparable ages. In the United States, their vegetation at the time of settlement was dominantly a tall grass prairie, but some of the soils on Pleistocene surfaces appear to have supported at some time a boreal forest that was supplanted by grasses several thousand years ago.

Udolls formed in sediments and on surfaces of varying ages, ranging from Holocene to mid Pleistocene or earlier. Those outside of glaciated areas may have formed during two or more glacial and interglacial stages.

Most of the Udolls are in the eastern part of the Great Plains or are east of the Great Plains. The soils are most extensive in Illinois, Iowa, and adjacent States. Where slopes are not too steep, nearly all of these soils are cultivated. Maize (corn) and soybeans are the major crops. Many Udolls have undergone significant erosion, which has resulted in mollic epipedons that are now noticeably thinner than they were in their native state.



Profile of a Udoll from the steppes of Ukraine. It has a very thick, very dark brown to black mollic epipedon about 120 cm thick. The right side of the profile has been smoothed.

Back to Udolls

Key to Great Groups of Udolls (Back to key to suborders)

Udolls that have:

1. **A natric (high levels of illuvial clay and sodium) horizon --- Natrudolls**

2. **A calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon within a depth of 100 cm AND free carbonates above -- Calciudolls**

3. **Either:**

   a) Cold average soil temperature (frigid soil temperature regime), an argillic (clay accumulation) horizon within a depth of 60 cm, and loamy or clayey textures above, OR

   b) A clay content that does not decrease significantly within a depth of 150 cm AND an argillic (clay accumulation) horizon with hue of 7.5YR or redder color in some part (and there is no root-limiting layer within a depth of 150 cm) --- Paleudolls
   Begin measuring depth below any O horizon. For item c, clay must not decrease by ≥ 20% of the maximum in the argillic horizon. See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding colors.

4. **An argillic (clay accumulation) horizon --------------------------- Argiudolls**

5. **Significant evidence of bioturbation ---------------------------- Vermudolls**
   Criterion requires ≥ 50% by volume in the surface layer and ≥ 25% in a transition zone to the subsoil below.

6. **A cambic (minimal soil development) horizon ----------------- Hapludolls**

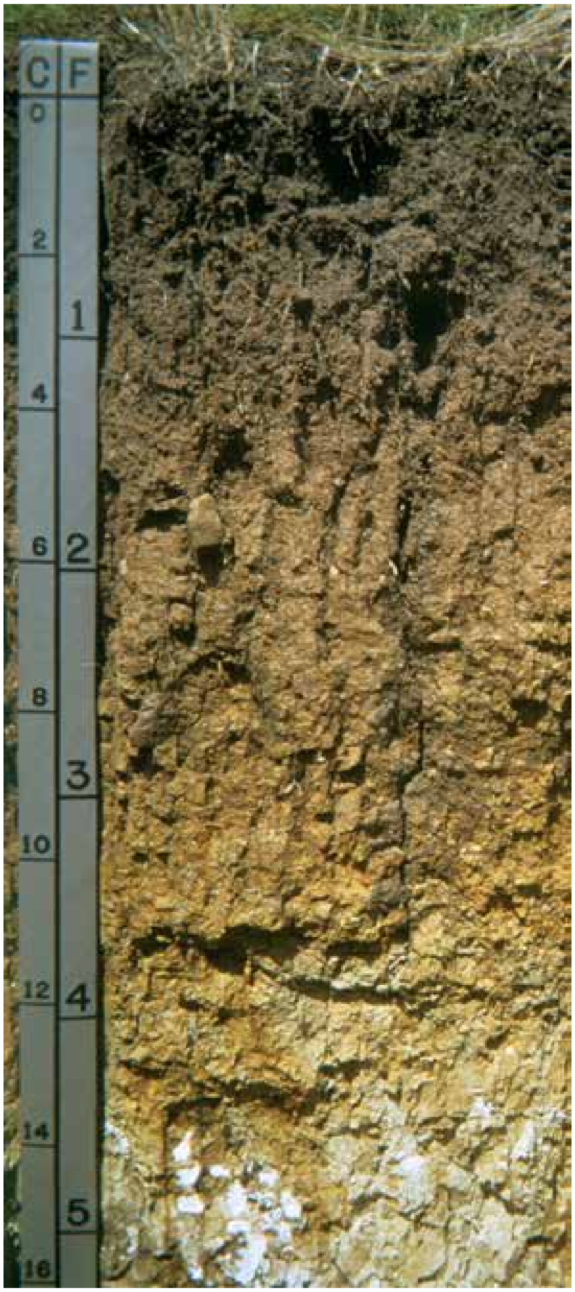
Descriptions of Great Groups of Udolls

Natrudolls—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon. Below the natric horizon, there is typically one horizon or more in which carbonates, sulfates, or other soluble salts have accumulated. Most Natrudolls are in small, nearly level or concave areas. These soils are most common in Argentina and on the northern Great Plains of the United States, where many of the parent materials contain salts. (Back to Udolls key)

Calciudolls—These soils have a calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) subsoil horizon that has its upper boundary within a depth of 100 cm. They are calcareous in all subhorizons overlying the calcic horizon after the upper 18 cm has been mixed, unless the texture is coarser than loamy very fine sand or very fine sand. These soils are of small extent on the northern Great Plains of the United States. They are important in Argentina. (Back to Udolls key)

Paleudolls—These soils have a thick or deep argillic (clay accumulation) subsoil horizon. Most of these soils have a reddish hue and a clay content that decreases very gradually with increasing depth. Paleudolls are mainly on surfaces older than Wisconsinan and are thought to have formed during at least one glacial stage and one interglacial stage. Slopes are gentle to steep. These soils are mostly on the southern Great Plains and in the mountains of the western United States. They are extensive only locally. (Back to Udolls key)

Argiudolls—These soils have a relatively thin argillic (clay accumulation) subsoil horizon or one in which the percentage of clay decreases greatly with increasing depth. The mollic (rich in humus and bases) epipedon commonly is black to very dark brown, and the argillic horizon is mostly brownish. Many of these soils are noncalcareous to a considerable depth below the argillic horizon. Some Argiudolls have a zone of accumulation of calcium carbonate below the argillic horizon. Argiudolls formed mostly in late-Wisconsinan deposits or on surfaces of that age. Many or most of these soils supported boreal forests during the Pleistocene that were later replaced by tall grass prairies during the Holocene. Argiudolls are extensive in Iowa, Illinois, and adjacent States. (Back to Udolls key)

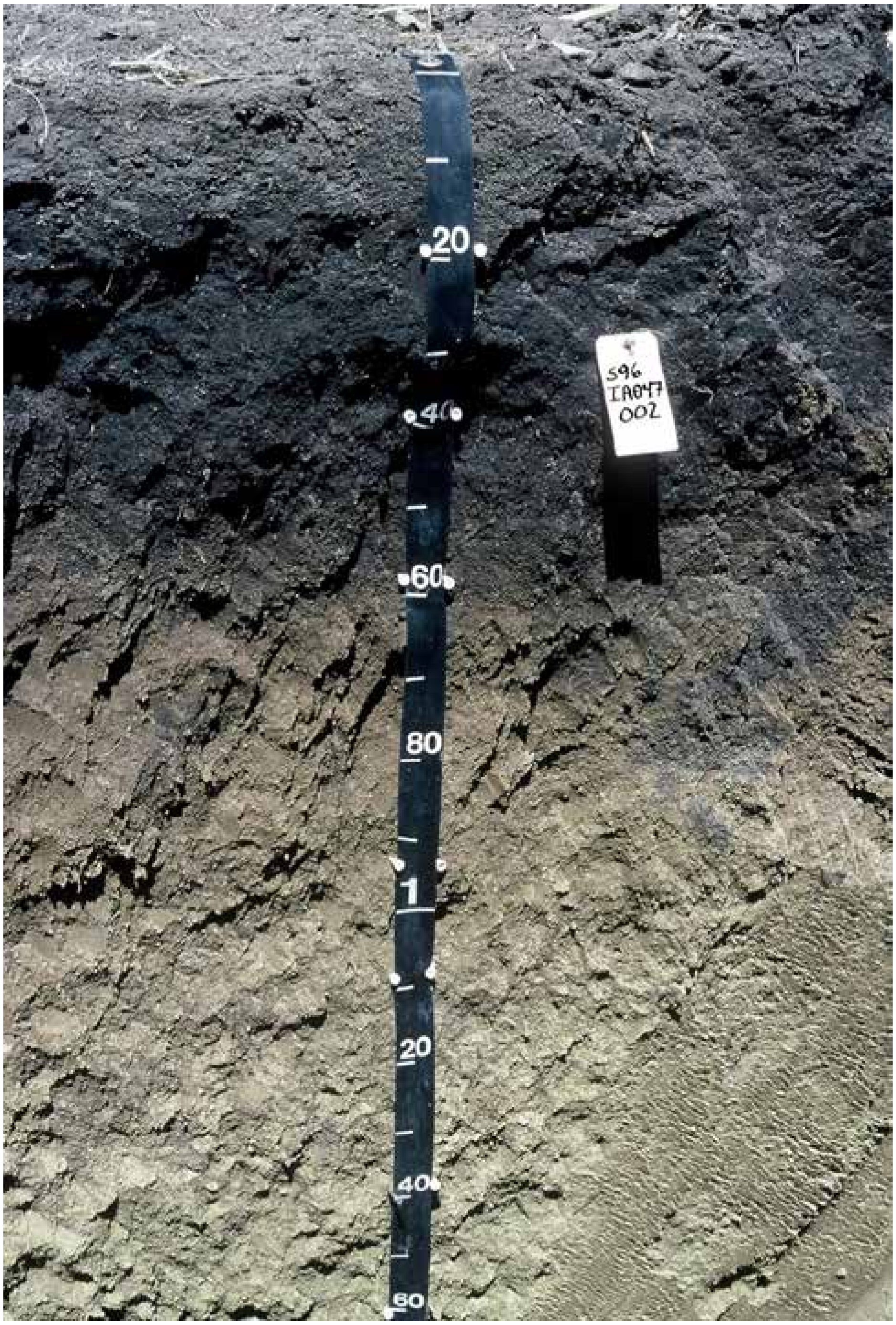


Profile of a moderately well drained Argiudoll in the eastern part of the Great Plains. It has a mollic epipedon about 40 cm thick underlain by an argillic horizon, which extends to a depth of about 130 cm. The argillic horizon has prismatic structure with dark organic stains on prism faces. Pockets of white, soft calcium carbonate are below a depth of about 130 inches.

Return to Argiudolls

Vermudolls—These soils have been intensively mixed by earthworms or other burrowing animals and their predators. The most common horizon sequence is a mollic (rich in humus and bases) epipedon consisting of many wormcasts that overlies soil material containing many worm channels filled with dark material from the mollic epipedon. These soils are not known to occur to a significant extent of the United States, but they are important in other countries. (Back to Udolls key)

Hapludolls—These soils generally have a cambic (minimal soil development) subsoil horizon below a mollic epipedon, but some only have a mollic epipedon and no other diagnostic horizons. There may be a zone of calcium carbonate accumulation below the cambic horizon. Hapludolls formed mostly in Holocene or late-Pleistocene deposits or on surfaces of that age. Slopes generally are gentle, and most of the soils are cultivated. Hapludolls are extensive in Iowa, Minnesota, and adjacent States. (Back to Udolls key)



Profile of a well drained Hapludoll in Iowa. This soil is on loess-covered hills and stream terraces along the Missouri River. It has a mollic epipedon about 60 cm thick and no other diagnostic horizons. The subsoil exhibits minimal soil development. Scale is in cm.

Return to Hapludolls

Oxisols Order

Oxisols are highly weathered tropical soils with low natural fertility.

General Characteristics

Oxisols are highly weathered soils that are low in natural fertility. Typically, they have an ochric (typically thin and/or light-colored) epipedon underlain by an oxic (extremely weathered) subsoil horizon. The oxic horizon is characterized by having a low nutrient-holding ability (i.e., cation-exchange capacity) and few minerals capable of further weathering. Oxisols with a clayey surface layer, but in which there is a noticeable further increase in clay content from the surface to the subsoil, have a kandic (very low cation-exchange capacity) subsoil horizon which is otherwise very similar to an oxic horizon. A few Oxisols have a sombric subsoil horizon (dark layer in which organic matter has accumulated). The processes leading to the formation of the sombric horizon are poorly understood. The profiles of most Oxisols are distinctive in that their horizons are not readily apparent visually. While their surface horizons are typically somewhat darker than the subsoil, the transition of subsoil features is gradual. Subsoil horizons are generally relatively red, due to iron oxides coating the mineral grains. Oxisols commonly have a strong grade of granular structure. Although they may have a loamy feel, many are in fact quite clayey. The clay particles are strongly aggregated into fine granules and, as a result, many Oxisols have a high degree of permeability.

Environment and Processes

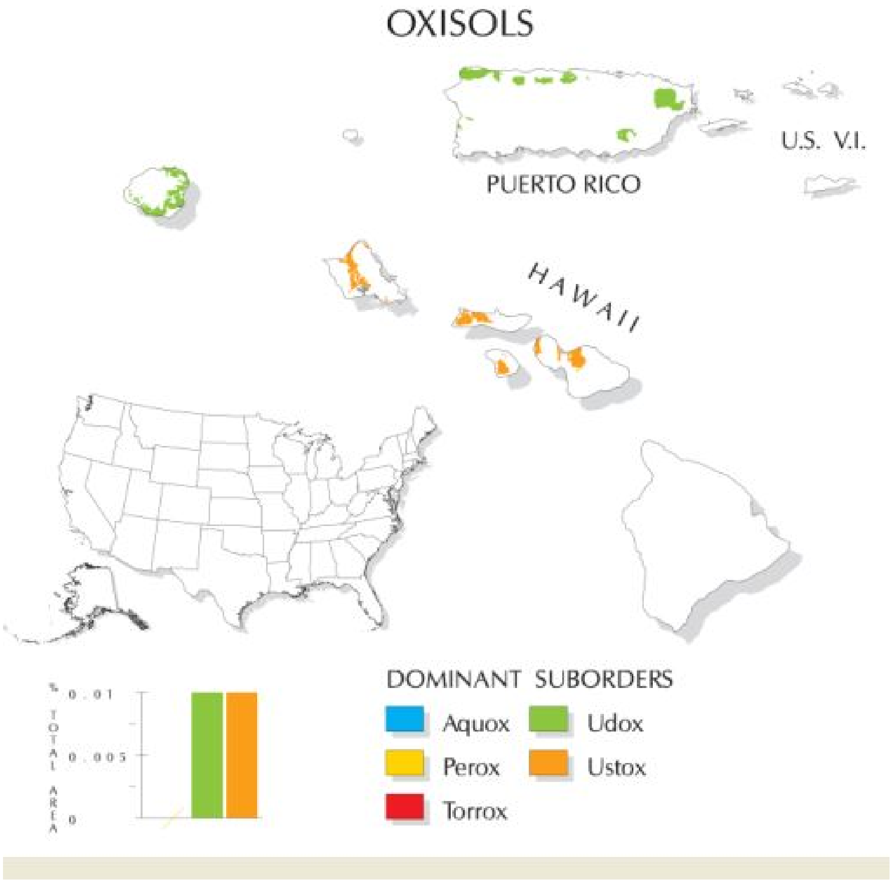
Oxisols occur mostly in the humid tropics and subtropics. They are generally in climates that are warm year-round with little seasonal variation. Because these soils occur in environments that range from tropical rainforests to grassland savannas and even include some deserts, they can have any soil moisture regime, from aquic to aridic. Many Oxisols are on old landscapes and formed in parent materials that have undergone multiple cycles of weathering, erosion, redeposition, and renewed weathering. In these soils, nearly all of the original weatherable minerals that were present early in the cycle are now gone, leaving only highly resistant minerals such as quartz, kaolinite, gibbsite, and oxides of aluminum and iron. From a mineralogical perspective, these soils are relatively inert and have little potential for further development. Oxisols have very low reserves of soil nutrients. Most of the soil nutrients are concentrated in the living and dead plant tissues at the site and are quickly lost when the site is cleared and cultivated. Oxisols can be fairly high in organic matter, but the organic matter is generally very old and consists of inactive, stable forms that do not add much to the fertility of the soil. Bioturbation, especially by termites, is important in many Oxisols.

Location

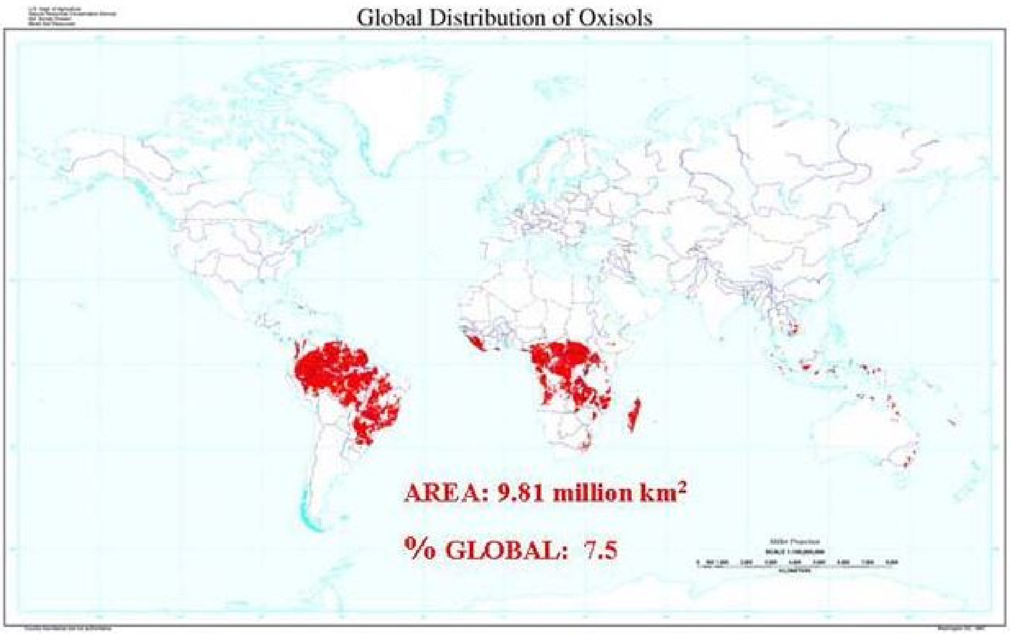
Globally, Oxisols occupy about 8% of the ice-free land area. They are found primarily at latitudes between the Tropic of Cancer and the Tropic of Capricorn (at latitudes of about 23 degrees north and south, respectively). The most extensive areas of Oxisols are on the interior plateaus of South America, the lower portion of the Amazon Basin, portions of the Central African Basin, and parts of Asia, Australia, and several tropical and subtropical islands. Oxisols are of small extent in the United States. They occur only in Hawaii and Puerto Rico, and many of the taxa are not known to occur at those locations.

Profile of an Oxisol.

(Back to Key to Soil Orders)



Oxisols by suborder in the United States.



Global distribution of Oxisols.

Oxisols Suborders

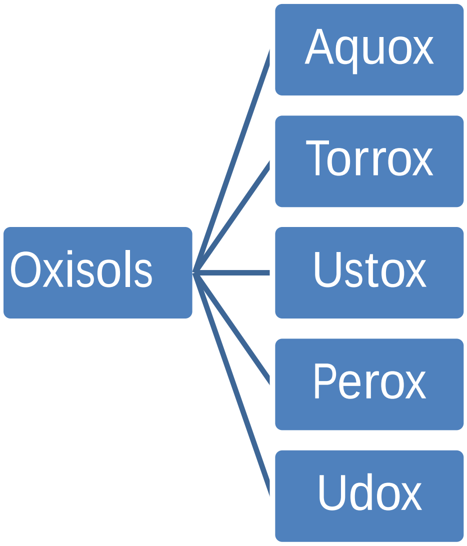
Classification of Oxisols

In the definitions of the suborders, emphasis is placed primarily on soil climate in the form of soil wetness (Aquox) and soil moisture regime (Torrox, Ustox, Perox, and Udox).

The great group level reflects a combination of important properties, including the presence of various diagnostic horizons, a very low effective cation-exchange capacity (ECEC), relatively high base saturation, and the presence of plinthite (firm, iron oxide-rich concentration) as a continuous phase in a layer.

The five suborders are:

1. Aquox—wet Oxisols (aquic conditions in the upper part)
2. Torrox—Oxisols of arid areas
3. Ustox—moderately dry Oxisols with limited moisture
4. Perox—Oxisols of areas where precipitation exceeds evaporation in all months
5. Udox—Oxisols of humid regions with well-distributed rainfall



Key to Suborders of Oxisols

Oxisols that have:

1. **A seasonal high water table within a depth of 50 cm --------------- Aquox**
   A histic epipedon (wet, organic surface layer) and/or redoximorphic features are evidence of a seasonal high water table. See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding depth and color of redoximorphic features. Begin measuring depth below any O horizon. Artificially drained soils are included in Aquox.

2. **Inadequate soil moisture for crop growth ------------------------------ Torrox**
   These soils have an aridic soil moisture regime.

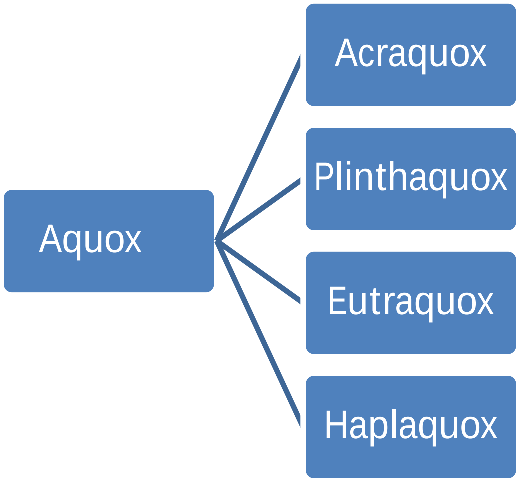
3. **Somewhat limited soil moisture available for crop growth -------- Ustox**
   These soils have either an ustic or xeric soil moisture regime.

4. **More total precipitation than evaporation each month ------------- Perox**
   These soils have a perudic soil moisture regime.

5. **Seasonally well-distributed precipitation -------------------------------- Udox**
   These soils have a udic soil moisture regime.

Aquox Great Groups

Aquox are the wet Oxisols in shallow depressions and in seepage areas at the base of slopes. They are saturated for long enough periods to allow the development of oxygen-depleted conditions within the upper 50 cm (aquic conditions), or they are artificially drained. Because the water table may fluctuate seasonally in the soils, iron tends to accumulate in the form of secondary nodules, concretions, and plinthite (firm, iron oxide-rich concentration). Most areas of these soils are small.



Profile of an Aquox in Brazil. The gray and reddish colors of the subsoil are due to saturation with water. Scale is in decimeters.

Back to Aquox

Key to Great Groups of Aquox (Back to key to suborders)

Aquox that have:

1. **An extremely low nutrient-holding capacity ---------------------- Acraquox**
   These soils have an effective cation-exchange capacity (ECEC) of < 1.50 cmol (+) per kg clay and a pH value (1N KCl) of ≥ 5.0 within a depth of 150 cm.

2. **Plinthite (firm, iron oxide-rich concentration) forming a continuous phase within a depth of 125 cm ----------------------------------- Plinthaquox**
   Begin measuring depth below any O horizon. Plinthite is a firm, iron oxide-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles.

3. **Moderate natural fertility -- Eutraquox**
   These soils have base saturation (by NH_4OAc) of ≥ 35% in all horizons within a depth of 125 cm.

4. **Low natural fertility -- Haplaquox**
   These soils have base saturation (by NH_4OAc) of < 35% in some horizon within a depth of 125 cm and an effective cation-exchange capacity (ECEC) of ≥ 1.50 cmol (+) per kg clay within a depth of 150 cm. Begin measuring depth below any O horizon.

Descriptions of Great Groups of Aquox

Acraquox—These soils have an extremely low cation-exchange capacity (CEC), and some have a net anion-exchange capacity. As a result, these soils have very little capacity to retain base cations (positively charged plant nutrients). Because of a low buffering capacity, small but frequent applications of fertilizer and lime may be needed. However, because the low CEC also facilitates the downward movement of the cations into the soil, careful nutrient management can lead to the enhancement of a favorable rooting depth for crops, especially where drainage is applied. (Back to Aquox key)

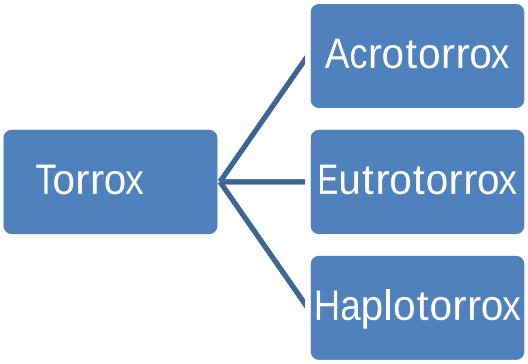
Plinthaquox—These soils have continuous plinthite (firm, iron oxide-rich concentration) within a depth of 125 cm. (Back to Aquox key)

Eutraquox—These soils have base saturation (measured by NH_4OAc at pH 7) of more than 35% in all horizons to a depth of 125 cm. Most formed in mafic (base-rich) parent materials. Although a significant proportion of the exchange sites are occupied by base cations (positively charged plant nutrients), the total CEC of these soils is still low. As a result, the initial supply of naturally occurring plant nutrients is rapidly depleted by cropping. (Back to Aquox key)

Haplaquox—These soils have a low base saturation in one or more subhorizons within a depth of 125 cm. (Back to Aquox key)

Torrox Great Groups

Torrox are the Oxisols of arid regions. They have an aridic moisture regime, and, due to limited leaching, many of them have a higher base saturation than other Oxisols. Unless they are irrigated, Torrox are unsuitable for growing common agronomic crops. However, they are well suited to a variety of crops if irrigation water and fertilizer are applied. Torrox are known to occur only in Hawaii in the United States and perhaps in some areas of Australia.



Profile of a Torrox (specifically a Haplotorrox) in Hawaii. This soil formed in residuum from a basaltic lava flow. Scale is in cm.

Back to Torrox

Key to Great Groups of Torrox (Back to key to suborders)

Torrox that have:

1. **An extremely low nutrient-holding capacity --------------------- Acrotorrox**
   These soils have an effective cation-exchange capacity (ECEC) of < 1.50 cmol (+) per kg clay and a pH value (1N KCl) of $\geq$ 5.0 within a depth of 150 cm.

2. **Moderate natural fertility -- Eutrotorrox**
   These soils have base saturation (by NH_4OAc) of $\geq$ 35% in all horizons within a depth of 125 cm.

3. **Low natural fertility --- Haplotorrox**
   These soils have base saturation (by NH_4OAc) of < 35% in some horizon within a depth of 125 cm and an effective cation-exchange capacity (ECEC) of $\geq$ 1.50 cmol (+) per kg clay within a depth of 150 cm. Begin measuring depth below any O horizon.

Descriptions of Great Groups of Torrox

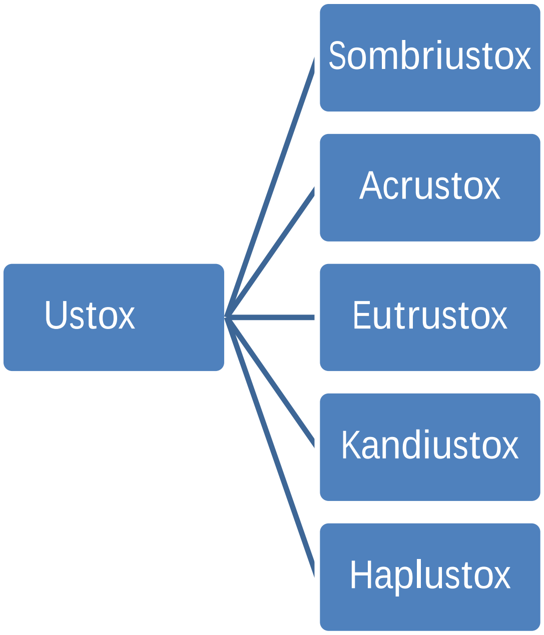
Acrotorrox—These soils have an extremely low cation-exchange capacity (CEC), and some have a net anion-exchange capacity. As a result, these soils have very little capacity to retain base cations (positively charged plant nutrients) such as Ca^{2+}, Mg^{2+}, and K^{+}. Because of a low buffering capacity, small but frequent applications of fertilizer and lime may be needed. However, because the low CEC also facilitates the downward movement of the cations into the soil, careful nutrient management can lead to the enhancement of a favorable rooting depth for crops. (Back to Torrox key)

Eutrotorrox—These soils have base saturation (measured by NH_4OAc at pH 7) of more than 35% in all horizons to a depth of 125 cm. Most formed in mafic (base-rich) parent material. Although a significant proportion of the exchange sites are occupied by base cations (positively charged plant nutrients), the total CEC of these soils is still low. As a result, the initial supply of naturally occurring plant nutrients is rapidly depleted by cropping. Eutrotorrox occur mainly in Hawaii, where they are used for irrigated crops. (Back to Torrox key)

Haplotorrox—These soils have a low base saturation in one or more subhorizons within a depth of 125 cm. (Back to Torrox key)

Ustox Great Groups

Ustox are the Oxisols of subhumid to semiarid climates. They have either an ustic (moisture is limited, but available, during portions of the growing season) or xeric (most moisture is supplied in winter) moisture regime. Due to the minimal difference between summer and winter temperatures, there is little practical distinction between the ustic and xeric regimes for these soils. Because of natural rainfall, these soils are moist in most years for at least 90 days (a period that usually is long enough for one rain-fed crop). Crops are not grown continuously because there is inadequate moisture for at least 90 days in most years. The range of natural rainfall for Ustox allows two crops to be grown in some areas but only one crop in other areas, unless supplemental irrigation is available. Ustox may be the most extensive suborder, occurring over a large portion of the interior of South America and in extensive areas of Africa. They are also found in Hawaii, Puerto Rico, and the Pacific Basin. A few Ustox are in areas with a xeric soil moisture regime, such as in Australia.



Profile of an Ustox (specifically a Eutrustox) in Rwanda. This soil is found at cool, high elevations and has a thick, dark umbric epipedon over the red oxic horizon. Scale is in decimeters.

Back to Ustox

Key to Great Groups of Ustox (Back to key to suborders)

Ustox that have:

1. **A sombric horizon (dark layer in which organic matter has accumulated) within a depth of 150 cm ------------------------ Sombriustox**
   Begin measuring depth below any O horizon.

2. **An extremely low nutrient-holding capacity ---------------------- Acrustox**
   These soils have an effective cation-exchange capacity (ECEC) of < 1.50 cmol (+) per kg clay and a pH value (1N KCl) of ≥ 5.0 within a depth of 150 cm. Begin measuring depth below any O horizon.

3. **Moderate natural fertility --- Eutrustox**
   These soils have base saturation (by NH_4OAc) of ≥ 35% in all horizons within a depth of 125 cm. Begin measuring depth below any O horizon.

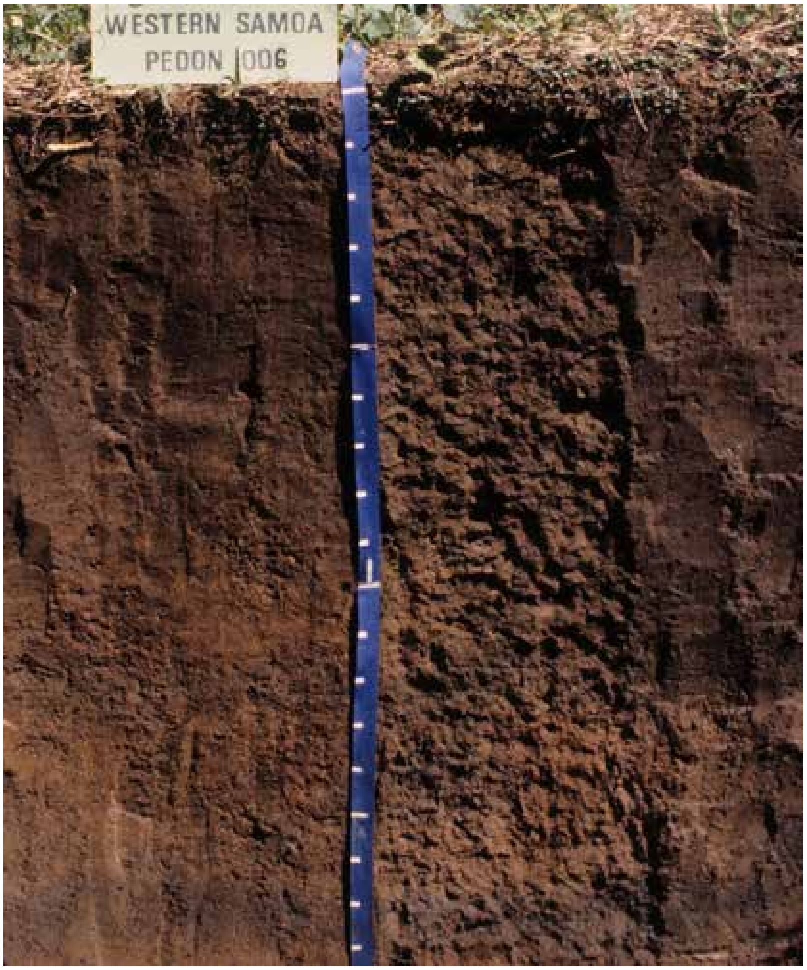
4. **A kandic (very low cation-exchange capacity) horizon within a depth of 150 cm -- Kandiustox**
   Begin measuring depth below any O horizon. These soils have < 10% weatherable minerals in the fine and very fine sand fraction of the kandic horizon, and there is a noticeable increase in clay from the clayey surface layer to the subsoil.

5. **Low natural fertility -- Haplustox**
   These soils have base saturation (by NH_4OAc) of < 35% in some horizon within a 125 cm and an effective cation-exchange capacity (ECEC) of ≥ 1.50 cmol (+) per kg clay within a depth of 150 cm. Begin measuring depth below any O horizon.

Descriptions of Great Groups of Ustox

Sombriustox—These soils have a sombric subsoil horizon (dark layer in which organic matter has accumulated). They have an increase in content of organic carbon in the subsoil. The subsoil is easily mistaken for a buried surface layer. Commonly, this layer has andic soil properties or some properties of spodic materials. The only known pedons of Sombriustox are near the Rift Valley in Africa. (Back to Ustox key)

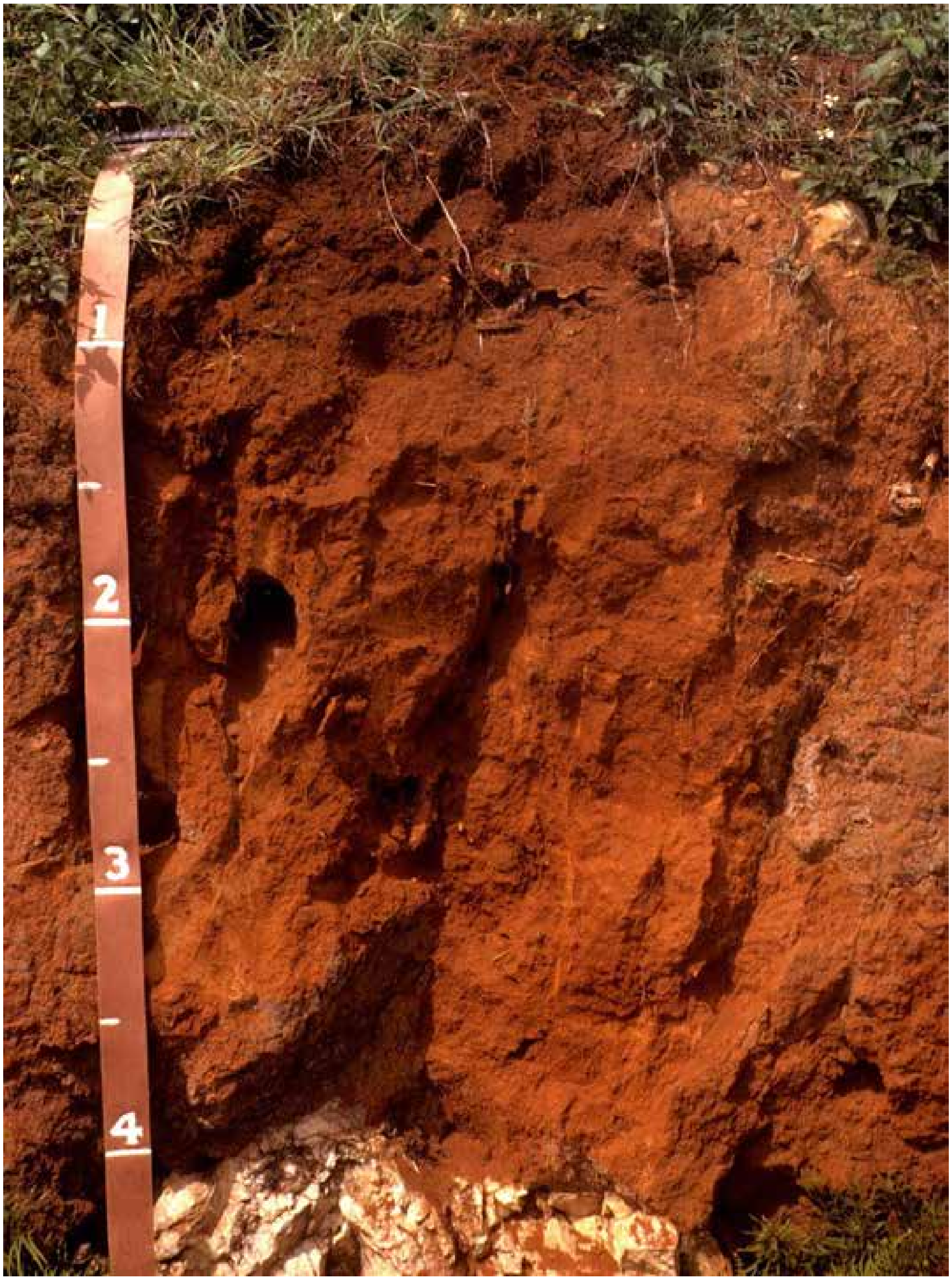
Acrustox—These soils have an extremely low cation-exchange capacity (CEC), and some have a net anion-exchange capacity. As a result, these soils have very little capacity to retain base cations (positively charged plant nutrients) such as Ca^{2+}, Mg^{2+}, and K^{+}. Because of a low buffering capacity, small but frequent applications of fertilizer and lime may be needed. However, because the low CEC also facilitates the downward movement of the cations into the soil, careful nutrient management can lead to the enhancement of a favorable rooting depth for crops. Supplemental irrigation is needed for continuous cropping. (Back to Ustox key)



Profile of a well drained Acrustox in a semiarid region of Western Samoa. This soil has an ochric epipedon about 10 cm thick underlain by an oxic horizon that extends to a depth of about 150 cm. It has very low natural fertility. In addition, because the clay minerals have a very low cation-exchange capacity or possibly even a slight net positive charge (thus anion-exchange activity), fertility management for this soil is very challenging. The part of the profile to the left of the tape has been smoothed. Scale is in 10-cm increments.

Return to Acrustox

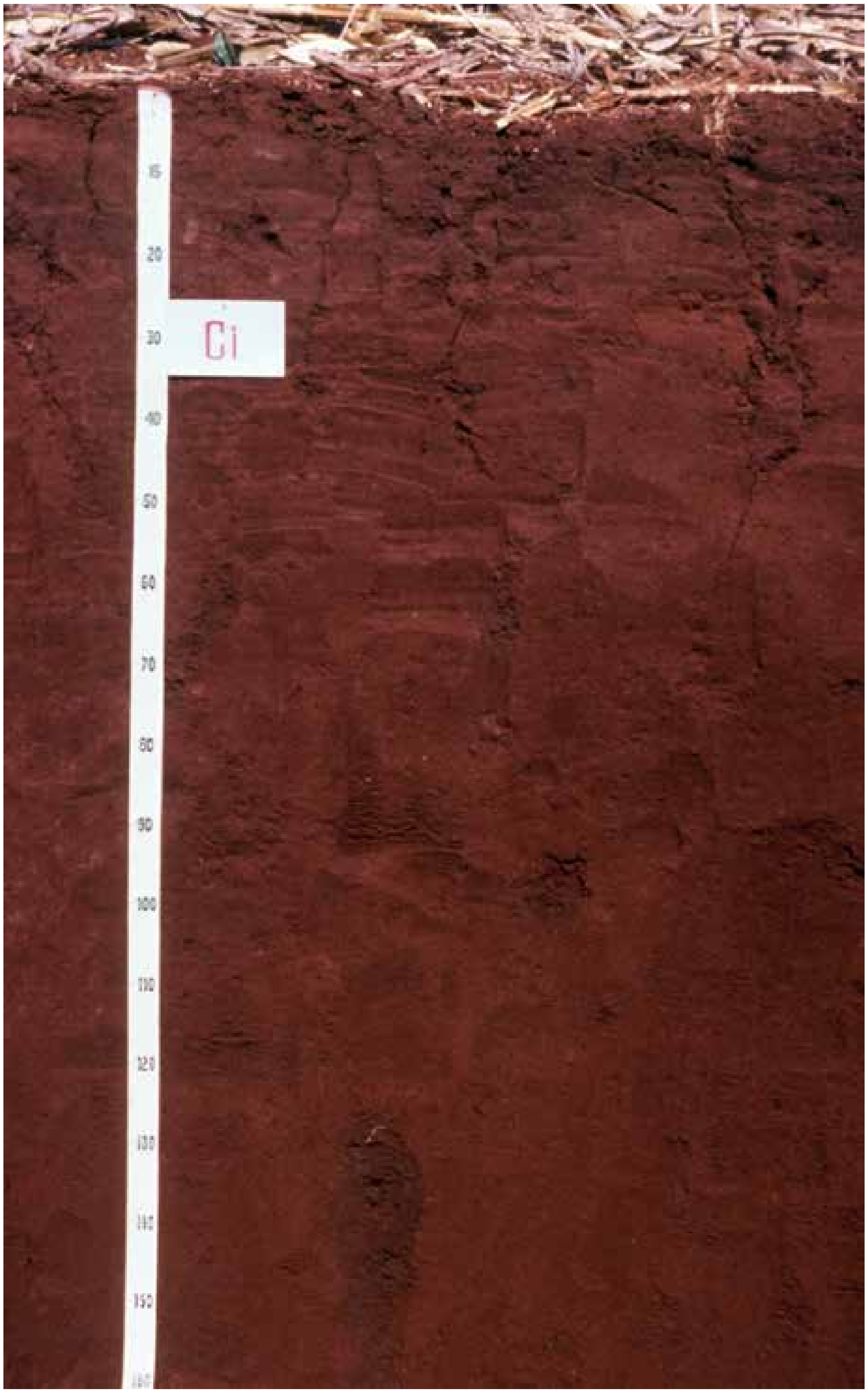
Eutrustox—These soils have high base saturation throughout the profile. They are well known by local farmers because of their relatively high natural fertility. Although a significant proportion of the exchange sites are occupied by base cations (positively charged plant nutrients), the total CEC of these soils is still low. As a result, the initial supply of naturally occurring plant nutrients is rapidly depleted by cropping. Supplemental irrigation is needed for continuous cropping. Commonly, these soils supported natural forests while the surrounding areas that had similar rainfall but low base saturation in the soil supported savannas. Currently, forest vegetation is rare because the forests have been completely cut by native farmers. The reason Ustox have high base saturation throughout their profile is not known, but these soils tend to occur over or near mafic (basic) rocks, such as limestone and basalt. (Back to Ustox key)



Profile of a well drained Eutrustox in a semiarid, tropical area of Jamaica. This soil has an ochric epipedon about 6 inches thick underlain by a reddish oxic horizon that extends to a depth of about 4 feet. Limestone bedrock is below 4 feet. This soil has a relatively high level of natural fertility compared to most other highly weathered tropical soils. Scale is in feet.

Return to Eutrustox

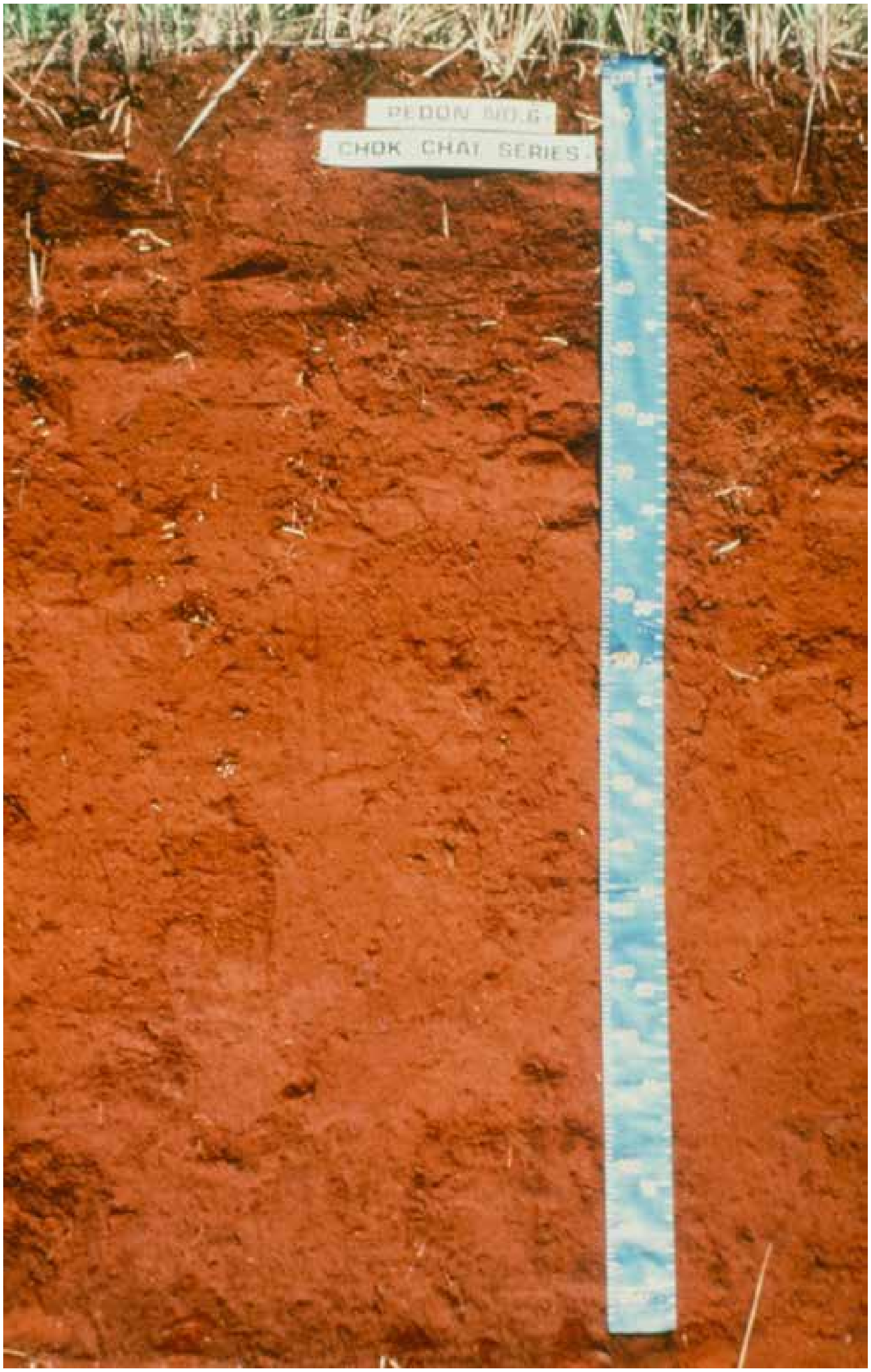
Kandiustox—These soils have a clayey surface layer and a kandic (very low cation-exchange capacity) subsoil horizon that has its upper boundary within a depth of 150 cm. There is a noticeable increase in clay content from the surface to the subsoil. They have, in all subhorizons of the kandic horizon within 150 cm of the mineral soil surface, an apparent ECEC of 1.50 or more cmol(+) per kg clay or a pH value (1N KCl) of less than 5.0. They also have base saturation (by NH_4OAc) of less than 35% in some horizon within a depth of 125 cm. The subsoil has a moderate grade of blocky structure in most pedons. The epipedons are either dark- or light-colored. The subsoil shows evidence of translocated clay only in a few areas. In some pedons, it tends to have a weak or moderate grade of blocky structure. In most of the soils, however, there is a strong secondary structure that is fine granular. Supplemental irrigation is needed for continuous cropping. (Back to Ustox key)



Profile of a red, clayey Kandiustox in Thailand. It has an ochric epipedon about 10 cm thick underlain by a kandic horizon that extends beyond the base of the photo. Although this soil has a high content of clay throughout, it has granular structure and so is porous. Scale is in 10-cm increments.

Return to Kandiustox

Haplustox—These soils have little difference in clay content between the surface and subsoil horizons. They have, in all subhorizons of an oxic horizon within a depth of 150 cm, an apparent ECEC of 1.50 or more cmol(+) per kg clay or a pH value (1N KCl) of less than 5.0. They have base saturation (by NH_4OAc) of less than 35% in some horizon within a depth of 125 cm. The subsoil has granular structure, and the epipedons may be either dark- or light-colored. Haplustox are dark red to yellow and have all intervening colors in the subsoil. They occur in vast areas of central South America and Africa. Supplemental irrigation is needed for continuous cropping. (Back to Ustox key)

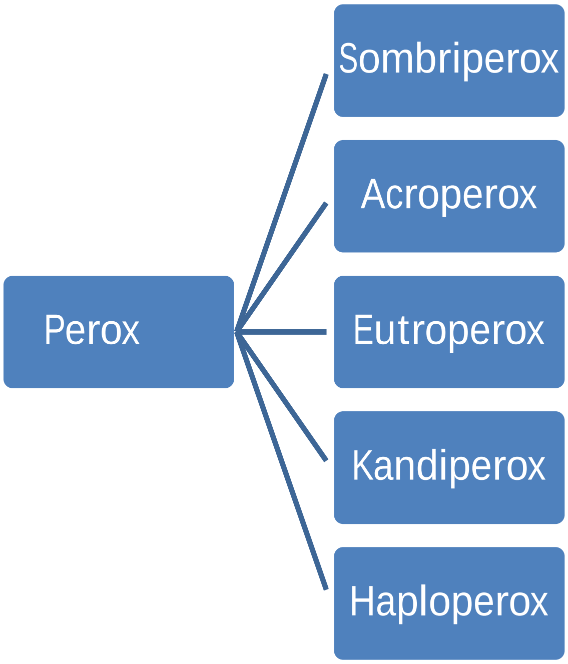


Profile of a Haplustox in a semiarid area of Thailand. This soil has an ochric epipedon about 10 cm thick underlain by a red oxic horizon. The left side of the scale is in 10-cm increments.

Return to Haplustox

Perox Great Groups

Perox are the well drained Oxisols of climates where precipitation exceeds evaporation in most months. They have a perudic soil moisture regime. Clearing and burning are difficult in areas of these soils because of atmospheric wetness. Curing many seed crops and storing produce are also difficult. There are no large areas with a perudic soil moisture regime, but areas of this regime appear distinctive enough to show and identify on some small-scale soil maps.



Perox soils are found on the highest mountains (in the background) of this Puerto Rican landscape. They receive much more precipitation than the soils in the foreground, which are Ustox.

Return to Perox

Key to Great Groups of Perox (Back to key to suborders)

Perox that have:

1. **A sombric horizon (dark layer in which organic matter has accumulated) within a depth of 150 cm ------------------------ Sombriperox**
   Begin measuring depth below any O horizon.

2. **An extremely low nutrient-holding capacity -------------------- Acroperox**
   These soils have an effective cation-exchange capacity (ECEC) of < 1.50 cmol (+) per kg clay and a pH value (1N KCl) of ≥ 5.0 within a depth of 150 cm. Begin measuring depth below any O horizon.

3. **Moderate natural fertility -- Eutroperox**
   These soils have base saturation (by NH_4OAc) of ≥ 35% in all horizons within a depth of 125 cm. Begin measuring depth below any O horizon.

4. **A kandic (very low cation-exchange capacity) horizon within a depth of 150 cm -- Kandiperox**
   Begin measuring depth below any O horizon. These soils have < 10% weatherable minerals in the fine and very fine sand fraction of the kandic horizon, and there is a noticeable increase in clay from the clayey surface layer to the subsoil.

5. **Low natural fertility --- Haploperox**
   These soils have base saturation (by NH_4OAc) of < 35% in some horizon within a depth of 125 cm and an effective cation-exchange capacity (ECEC) of ≥ 1.50 cmol (+) per kg clay within a depth of 150 cm. Begin measuring depth below any O horizon.

Descriptions of Great Groups of Perox

Sombriperox—These soils have a sombric subsoil horizon (dark layer in which organic matter has accumulated). They are not known to occur in the United States but are expected to be found in other parts of the world. (Back to Perox key)

Acroperox—These soils have an extremely low cation-exchange capacity (CEC), and some have a net anion-exchange capacity. As a result, these soils have very little capacity to retain base cations (positively charged plant nutrients) such as Ca^{2+}, Mg^{2+}, and K^{+}. (Back to Perox key)

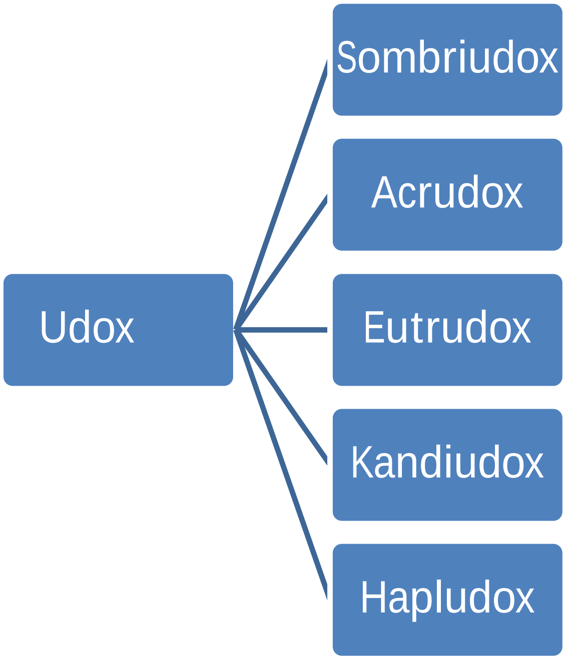
Eutroperox—These soils have high base saturation throughout the profile. Although a significant proportion of the exchange sites are occupied by base cations (positively charged plant nutrients), the total CEC of these soils is still low. As a result, the initial supply of naturally occurring plant nutrients is rapidly depleted by cropping. (Back to Perox key)

Kandiperox—These soils have a clayey surface layer and a kandic (very low cation-exchange capacity) horizon that has its upper boundary within a depth of 150 cm. There is a noticeable increase in clay content from the surface to the subsoil. These soils have, in all subhorizons within a depth of 150 cm, an apparent ECEC of 1.50 or more cmol(+) per kg clay or a pH value (1N KCl) of less than 5.0. They also have base saturation (by NH_4OAc) of less than 35% in some horizon within a depth of 125 cm. The subsoil has granular structure, and the epipedons may be either dark- or light-colored. (Back to Perox key)

Haploperox—These soils have little difference in clay content between the surface and subsoil layers. They have, in all subhorizons of an oxic horizon within a depth of 150 cm, an apparent ECEC of 1.50 or more cmol(+) per kg clay or a pH value (1N KCl) of less than 5.0. They also have base saturation (by NH_4OAc) of less than 35% in some horizon within a depth of 125 cm of the mineral soil surface. The subsoil has granular structure, and the epipedons may be either dark- or light-colored. (Back to Perox key)

Udox Great Groups

Udox are the well drained Oxisols of areas with seasonally well-distributed precipitation. They have a udic soil moisture regime. They are moist because of natural rainfall in most years and are dry in some parts for less than 90 days, a period that is short enough for rain-fed crops to be grown continuously in most years. There are fewer than 90 days during which crops are not planted. In local terms, there are 1 to 3 months that are considered dry in most years. Udox are an extensive suborder, occurring mostly in South America and in parts of Africa and Asia.



Profile of a Udox in Puerto Rico. This soil is an Acrudox and therefore has a very low nutrient-holding capacity.

Return to Udox

Key to Great Groups of Udox (Back to key to suborders)

Udox that have:

1. **A sombric horizon (dark layer in which organic matter has accumulated) within a depth of 150 cm ------------------------ Sombriudox**
   Begin measuring depth below any O horizon.

2. **An extremely low nutrient-holding capacity ----------------------- Acrudox**
   These soils have an effective cation-exchange capacity (ECEC) of < 1.50 cmol (+) per kg clay and a pH value (1N KCl) of ≥ 5.0 within a depth of 150 cm. Begin measuring depth below any O horizon.

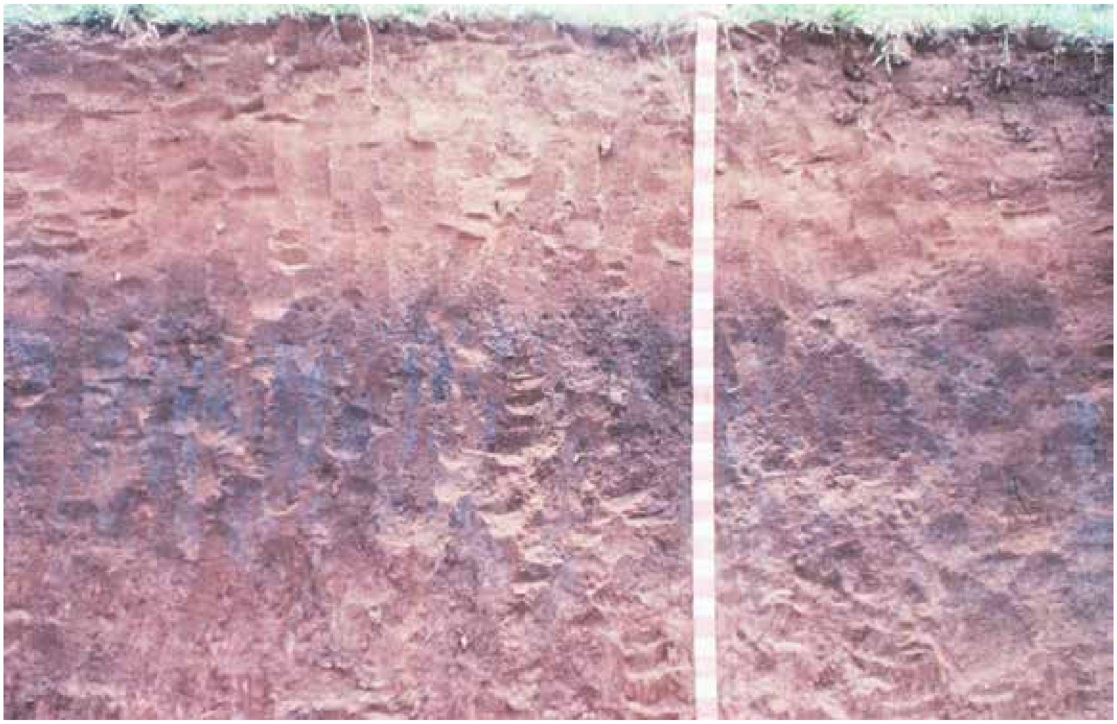
3. **Moderate natural fertility -- Eutrudox**
   These soils have base saturation (by NH_4OAc) of ≥ 35% in all horizons to a depth of 125 cm. Begin measuring depth below any O horizon.

4. **A kandic (very low cation-exchange capacity) horizon within a depth of 150 cm -- Kandiudox**
   These soils have < 10% weatherable minerals in the fine and very fine sand fraction of the kandic horizon, and there is a noticeable increase in clay from the clayey surface layer to the subsoil. Begin measuring depth below any O horizon.

5. **Low natural fertility --- Hapludox**
   These soils have base saturation (by NH_4OAc) of < 35% in some horizon within a depth of 125 cm and an effective cation-exchange capacity (ECEC) of ≥ 1.50 cmol (+) per kg clay within a depth of 150 cm. Begin measuring depth below any O horizon.

Descriptions of Great Groups of Udox

Sombriudox—These soils have a sombric subsoil horizon (dark layer in which organic matter has accumulated). They are poorly understood. They have an increase in content of organic carbon in the subsoil. The only known pedons are near the Rift Valley in Africa. (Back to Udox key)



Profile of a Sombriudox in Rwanda. The dark-colored sombric horizon, which is between depths of 80 and 130 cm (running through center of photo), is between redder oxic horizons. Scale colors are in 5-cm increments.

Return to Sombriudox

Acrudox—These soils have an extremely low cation-exchange capacity, and some have a net anion-exchange capacity. As a result, these soils have very little capacity to retain base cations (positively charged plant nutrients) such as Ca^{2+}, Mg^{2+}, and K^{+}. Frequent but small applications of fertilizer and lime are required for agriculture. Because the low CEC also facilitates the downward movement of these cations into the soil, careful nutrient management can lead to the enhancement of a favorable rooting depth for crops. Also, because CEC is low, the amount of exchangeable aluminum in the subsoil is low. This deficiency can be corrected by leaching basic cations from lime and fertilizer. (Back to Udox key)

Eutrudox—These soils have high base saturation throughout the profile. Although a significant portion of the exchange sites are occupied by base cations (positively charged plant nutrients), the total CEC of these soils is still low. As a result, the initial supply of naturally occurring plant nutrients is rapidly depleted by cropping. Eutrudox are highly valued by shifting cultivators and are most common in areas near mafic (basic) rock. (Back to Udox key)

Kandiudox—These soils have a clayey surface layer and a kandic (very low cation-exchange capacity) subsoil horizon that has its upper boundary within a depth of 150 cm. There is a noticeable increase in clay content from the surface layer to the subsoil. These soils have, in all subhorizons of a kandic horizon within a depth of 150 cm, an apparent ECEC of 1.50 or more cmol(+) per kg clay or a pH value (1N KCl) of less than 5.0. They also have base saturation (by NH_4OAc) of less than 35% in some horizon within a depth of 125 cm. The subsoil has a moderate grade of blocky structure in most pedons. The epipedons are either dark- or light-colored. (Back to Udox key)

Hapludox—These soils have little difference in clay content between the surface and subsoil layers. They have, in all subhorizons of an oxic horizon within a depth of 150 cm, an apparent ECEC of 1.50 or more cmol(+) per kg clay or a pH value (1N KCl) of less than 5.0. They also have base saturation (by NH_4OAc) of less than 35% in some horizon within 125 cm of the mineral soil surface. The subsoil has granular structure, and the epipedons may be either dark- or light-colored. These soils commonly are acid, and the subsoil ranges from dark red to pale yellow. Hapludox are common in the uplands of Africa, the central part of Indonesia, and many other areas. (Back to Udox key)

Spodosols Order

Spodosols are acid soils with low fertility and accumulations of organic matter and iron and aluminum oxides in the subsoil.

General Characteristics

The dominant profile characteristic of Spodosols is a reddish or brownish spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. Commonly, there is an albic (light-colored and leached) horizon above the spodic horizon. Spodosols tend to be quite acid throughout the profile. Some Spodosols have additional kinds of horizons below the spodic horizon, such as a root-restrictive fragipan (firm and brittle but not cemented layer) or a clay-enriched argillic horizon. A few Spodosols have an iron-cemented placic horizon. Most Spodosols are sandy, and a few are loamy.

Environment and Processes

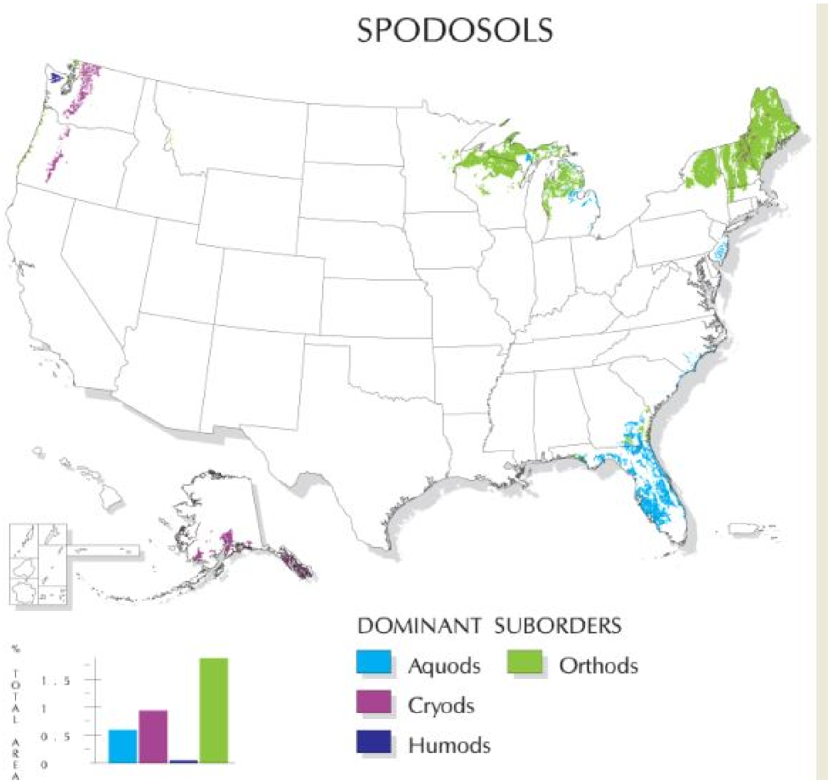
Spodosols are most extensive in areas of cool, moist climates in the humid boreal zones. Most are well drained to somewhat poorly drained. A few Spodosols, however, are in warm tropical or sub-tropical regions, mostly in areas of quartz-rich sands that have a fluctuating level of ground water. Spodosols formed mostly in sandy or loamy parent materials under coniferous forest vegetation. Some are in hardwood forests, in tropical rainforests, or under palms. The critical processes leading to the formation of these soils include the production of organic acids from decaying leaf litter. These acids form organo-metallic complexes with iron and aluminum, which then move downward in the profile and accumulate in the subsoil. Spodosols are very acid and low in native fertility.

Location

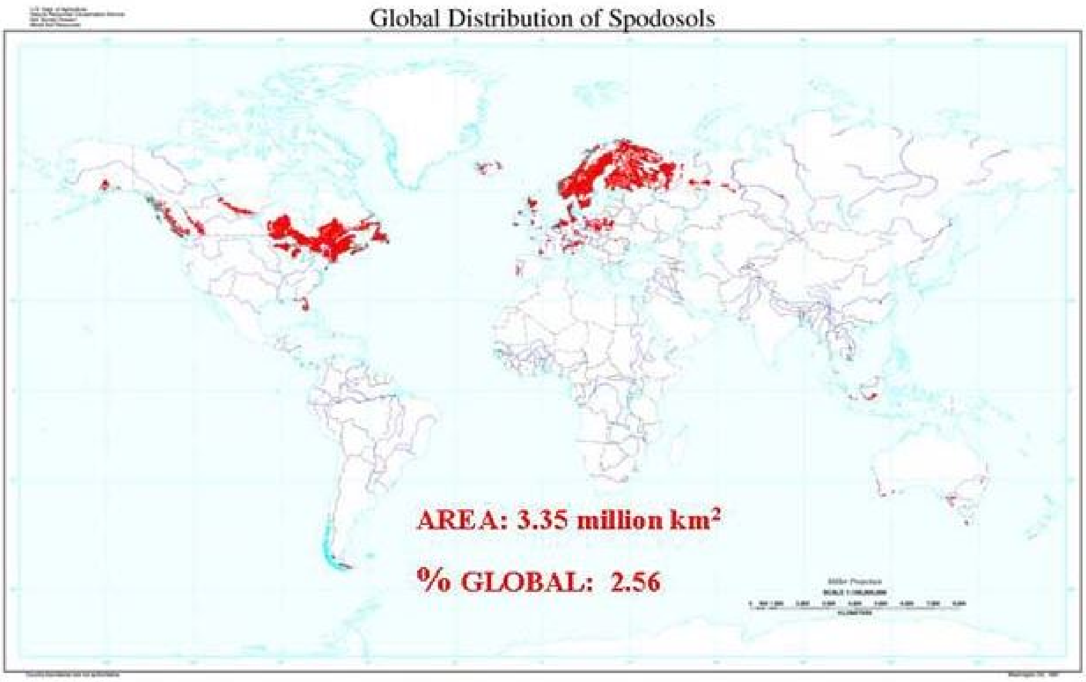
Globally, Spodosols occupy about 3% of the ice-free land area. In North America, Spodosols are common in the Great Lakes region, New England, and eastern Canada. They are also found in the Pacific Northwest and southern Alaska as well as on the coastal plain of the southeastern United States. Spodosols are common in northern Europe and Russia and are also found in New Zealand and southern Australia.

Profile of a Spodosol.

(Back to Key to Soil Orders)



Spodosols by suborder in the United States. Note: This map was produced before the introduction of the Gelods suborder. Some areas shown as Cryods in Alaska are now Gelods.



Global distribution of Spodosols.

Spodosols Suborders

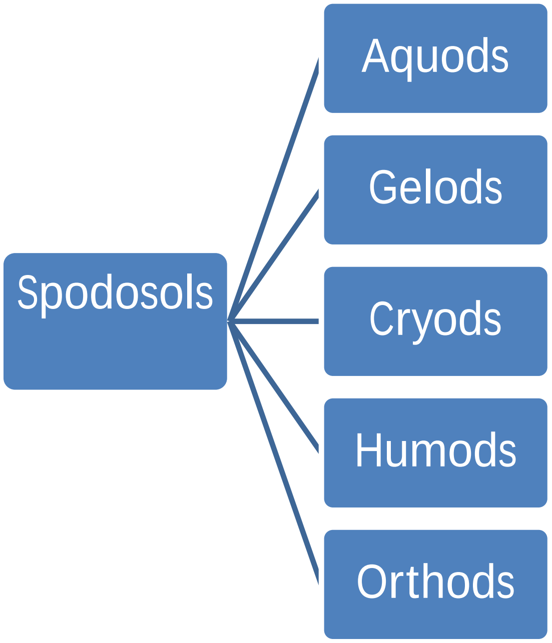
Classification of Spodosols

In the definitions of the suborders, emphasis is divided between soil wetness (Aquods), cold soil temperatures (Gelods and Cryods), spodic horizons dominated by illuvial accumulation of organic matter (Humods), and varying amounts of illuvial carbon, aluminum, and iron in the spodic horizons (Orthods).

The great group level reflects a combination of important properties, including the presence of diagnostic horizons other than a spodic horizon, the presence of cemented layers, prevalence of either aluminum or carbon as illuvial constituents, cold soil temperature, and kinds of soil saturation.

The five suborders are:

1. Aquods—wet Spodosols (aquic conditions in the upper part)
2. Gelods—very cold Spodosols that lack permafrost (gelic temperature regime)
3. Cryods—cold Spodosols (cryic temperature regime)
4. Humods—Spodosols with a large accumulation of carbon in the spodic horizon
5. Orthods—simple Spodosols with varying amounts of illuvial carbon, aluminum, and iron in the spodic horizon



Key to Suborders of Spodosols

Spodosols that have:

1. **A seasonal high water table within a depth of 50 cm ------------- Aquods**
   Evidence of the water table may be a histic epipedon (wet, organic surface layer) and/or redoximorphic features (gray and red color patterns). See 12th edition of "Keys to Soil Taxonomy" for specific criteria regarding location of redoximorphic features. Begin measuring depth below any O horizon. Artificially drained soils are included in Aquods.

2. **Very cold average soil temperature ------------------------------------ Gelods**
   These soils have a gelic soil temperature regime.

3. **Cold average soil temperature --- Cryods**
   These soils have a cryic soil temperature regime.

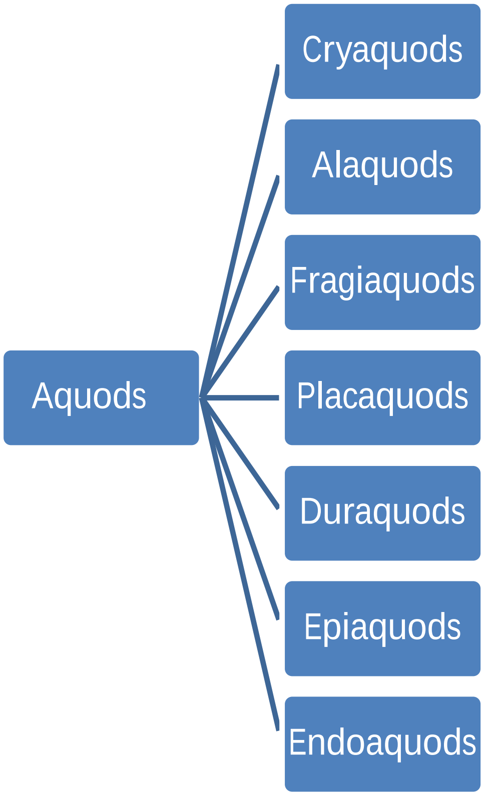
4. **High amounts of organic carbon in the subsoil ------------------- Humods**
   These soils have $\geq$ 6.0% organic carbon in a layer $\geq$ 10 cm thick within the spodic horizon.

5. **A simple spodic horizon -- Orthods**
   These soils have varying amounts of illuvial carbon, aluminum, and iron in the spodic horizon but have $\leq$ 6.0% organic carbon in all layers $\geq$ 10 cm thick within the spodic horizon.

Aquods Great Groups

Aquods are the wet Spodosols. They are saturated close to the surface for a long enough period during the year to become devoid of oxygen (aquic conditions). Most of the soils have a nearly white albic (light-colored and leached) horizon thick enough to persist under cultivation or have, where they are the wettest, a black surface horizon resting on a dark reddish brown spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon that is virtually free of iron. Other Aquods have a placic (cemented by iron and organic matter) horizon or a duripan (layer cemented by silica) or are cemented by an amorphous mixture of sesquioxides and organic matter. The Aquods that do not have a placic horizon typically have a transitional horizon between the albic horizon and the spodic horizon.

Aquods formed mainly in sandy materials of Pleistocene age. They may have any soil temperature regime. Water-loving plants of a very wide variety, ranging from sphagnum in cold areas to palms in the tropics, grow on these soils. In the United States, except in New Jersey and Florida, relatively few Aquods are cultivated.



Profile of an Aquod (specifically an Alaquod) in Florida. The spodic horizon (black) begins at a depth of about 62 cm.

Back to Aquods

Key to Great Groups of Aquods (Back to key to suborders)

Aquods that have:

1. **Cold average soil temperature -------------------------------------- Cryaquods**
   These soils have a cryic soil temperature regime.

2. **A very low content of iron in the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) horizon --- Alaquods**
   These soils have < 0.10% iron (by ammonium oxalate) in ≥ 75% of the spodic horizon.

3. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm --- Fragiaquods**
   Begin measuring depth below any O horizon.

4. **A placic (cemented by iron and organic matter) horizon within a depth of 100 cm --- Placaquods**
   Begin measuring depth below any O horizon. The placic horizon is present in ≥ 50% of each pedon. By definition, a placic horizon in Spodosols is ≤ 2.5 cm thick.

5. **A cemented soil layer within a depth of 100 cm -------------- Duraquods**
   Begin measuring depth below any O horizon. The cemented layer is present in ≥ 90% of each pedon.

6. **Episaturation (perched water table) ------------------------------- Epiaquods**

7. **Endosaturation (saturated throughout the profile) --------- Endoaquods**

Descriptions of Great Groups of Aquods

Cryaquods—These soils occur in cold climates, mainly at high latitudes. Because they are both cold and wet, Cryaquods are generally precluded from cropping. Most are covered with coniferous forest or tundra vegetation. Aquic conditions (saturated and depleted of oxygen) persist during much of the growing season. In the United States, Cryaquods occur in Alaska. (Back to Aquods key)

Alaquods—These soils have a water table that fluctuates seasonally. During wet periods, iron is chemically reduced (thus making it mobile) and moved out of the soil profile. The spodic horizon consists mostly of an accumulation of organic matter and aluminum and commonly has few or no redoximorphic concentrations (reddish to black accumulations of iron-manganese oxides). The albic (light-colored and leached) horizon in the drier Alaquods is typically thick. The wettest Alaquods have no albic horizon but generally have uncoated sand grains above the spodic horizon. Alaquods typically have sandy texture. Because of their high humus content, however, some of them feel and behave like loamy soils. Alaquods occur primarily in the southeastern United States. (Back to Aquods key)

Profile of a sandy, somewhat poorly drained Alaquod in Florida. This soil has a light gray albic horizon between depths of 6 and 55 cm. This horizon has been leached of aluminum and organic matter, which have accumulated in the dark brown spodic horizon below. Note the three circular bodies of albic material surrounded by spodic material at a depth of about 80 cm. The origin of these features in this profile is not known, but they may be related to animal burrowing or former tree root pathways. Scale is in centimeters.

Return to Alaquods

Fragiaquods—These soils have a fragipan (firm and brittle but not cemented layer) below the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) horizon, typically at a depth of 40 to 75 cm. Plant roots are shallow, and the soil clinging to the roots of tree-throws has in many areas formed a microrelief of 20 to 50 cm. Most of these soils are in fairly cold regions. Although these soils are nearly level, few of them are cultivated, except for those used for the production of hay. Most are forested. Fragiaquods are not extensive in the United States. (Back to Aquods key)

Placaquods—These soils have a thin (≤ 2.5 cm) placic (cemented by iron and organic matter) horizon. The placic horizon commonly has a very irregular (involute) boundary. The horizons above the placic horizon have low-contrast mottles that are probably caused by organic matter. Placaquods are known to occur only in areas of perhumid oceanic climates. Many have, or used to have, sphagnum and heath vegetation. (Back to Aquods key)

Duraquods—These soils have a cemented soil layer that in many areas is a combination of iron and/or aluminum and organic matter. In some of these soils, silica also is a cementing agent. Duraquods are seasonally saturated above the cemented soil layer but not necessarily below it. In the United States, these soils occur mostly in the Pacific Northwest and in the Lakes States region. They also are known to occur in New Zealand, in areas of kauri trees. The cemented soil layer in Duraquods severely restricts plant rooting. Currently, few of these soils are recognized worldwide. (Back to Aquods key)

Profile of a poorly drained Duraquod in Washington State. This soil has an ochric epipedon that has been plowed to a depth of about 25 to 30 cm. The subsoil below a depth of about 45 to 50 cm is a spodic horizon cemented by an accumulation of iron and organic matter. The profile to the left of the tape has been smoothed; the right side retains the natural soil structure. Scale is in cm.

Return to Duraquods

Epiaquods—These soils have a perched water table above one or more relatively impermeable layers. They typically have a considerable accumulation of iron in addition to aluminum and organic matter. The relatively impermeable layers commonly are argillic (clay accumulation) subsoil horizons or dense, compacted glacial till. (Back to Aquods key)

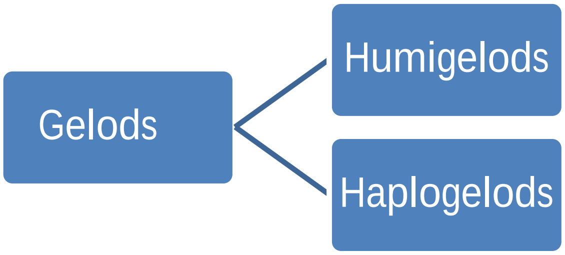
Endoaquods—These soils are saturated throughout the soil profile. They have a considerable accumulation of iron, in addition to aluminum and organic carbon, in the spodic horizon. The spodic horizon has few to many redoximorphic features (gray and red color patterns) and commonly is brown to dark reddish brown. Most Endoaquods have an albic (light-colored and leached) horizon. Some of the wettest do not have an albic horizon but commonly have uncoated sand grains above the spodic horizon. (Back to Aquods key)

Profile of a somewhat poorly drained, sandy Endoaquod. This soil has an ochric epipedon consisting of a thin (2 to 3 cm) surface layer and an underlying thick, white albic horizon that has a wavy lower boundary. The albic horizon ranges from about 15 to 35 cm in thickness. Below this horizon is a spodic horizon that extends beyond the base of the photo. The spodic horizon is black in the upper part (about 20 cm thick) and reddish brown with dark brown streaks and sublayers below. Note the water table in the lower part of the profile. The length of the auger is about 1 m.

Return to Endoaquods

Gelods Great Groups

Gelods are the Spodosols of very cold, high-latitude regions. They have a gelic temperature regime but lack permafrost within the profile. These soils tend to be in landscape positions that are subject to wide variations in summer high temperatures and winter low temperatures, which result in mean annual soil temperatures of 0 degrees C or less, but without permafrost.



Profile of a Gelod (specifically a Humigelod) in Alaska. The surface layer (upper third of photo) is a histic epipedon. It is underlain by a gray albic horizon about 15 cm thick. Below this is a spodic horizon (about 30 cm thick) that is dark brown in its upper part and reddish brown in its lower part. The profile extends to a depth of about 1 meter.

Return to Gelods

Key to Great Groups of Gelods (Back to key to suborders)

Gelods that have:

1. **High amounts of organic carbon in the subsoil -------------- Humigelods**
   These soils have ≥ 6.0% organic carbon in a layer ≥ 10 cm thick within the spodic horizon.

2. **A simple spodic horizon --- Haplogelods**

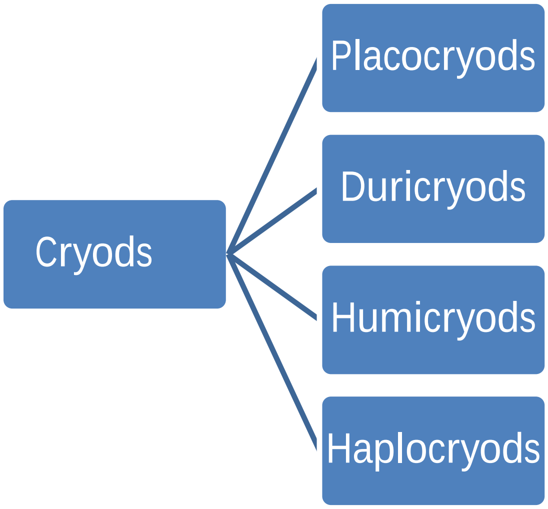
Descriptions of Great Groups of Gelods

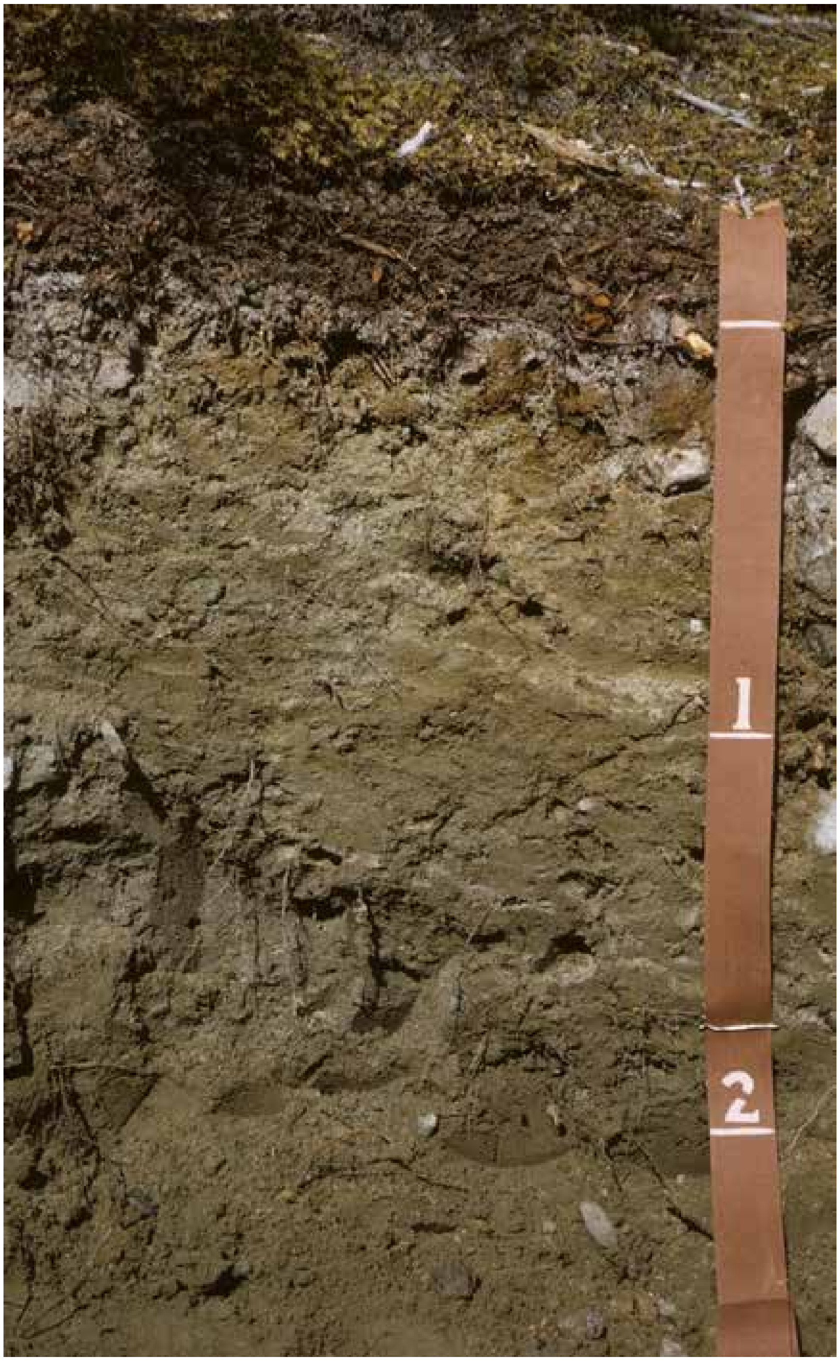
Humigelods—These soils commonly have an O horizon over a very thin or intermittent albic (light-colored and leached) horizon, which overlies a dark-colored spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. They have a high content of organic carbon in the upper part of the spodic horizon. The vegetation commonly is coniferous forest or alpine tundra. Humigelods are not extensive. In the United States, they occur in Alaska. (Back to Gelods key)

Haplogelods—These soils are mostly well drained or excessively drained. Most have high contents of rock fragments in the profile. They commonly have a thin ochric (typically thin and/or light-colored) epipedon, and possibly an albic (light-colored and leached) horizon, over a spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. The vegetation commonly is coniferous forest or alpine tundra. Haplogelods are not extensive. In the United States, they occur in Alaska. (Back to Gelods key)

Cryods Great Groups

Cryods are Spodosols of high latitudes and/or high elevations. In the United States, they occur mostly in southeast Alaska and in the mountains of Washington, Oregon, and northern Idaho. Some are in the mountains of New York and northern New England. Many Cryods formed in volcanic ash or glacial drift, and some formed in residuum or colluvium on mountain slopes. Cryods commonly have an O horizon over a very thin or intermittent albic (light-colored and leached) horizon, which overlies a well developed spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. Some of the soils have a thin placic (cemented by iron and organic matter) horizon or another cemented soil layer within a depth of 100 cm. In many Cryods, the content of organic carbon in the upper part of the spodic horizon is relatively high. The vegetation is mostly coniferous forest or alpine tundra.





Profile of a Cryod (specifically a Haplocryod) in Alaska. This soil formed in glacial till that is only about 200 years old. The thin albic and spodic horizons are within the upper 1 foot of the profile. Scale is in feet.

Back to Cryods

Key to Great Groups of Cryods (Back to key to suborders)

Cryods that have:

1. **A placic (cemented by iron and organic matter) horizon within a depth of 100 cm --- Placocryods**
Begin measuring depth below any O horizon. The placic horizon is present in ≥ 50% of each pedon. By definition, a placic horizon in Spodosols is ≤ 2.5 cm thick.

2. **A cemented soil layer within a depth of 100 cm --------------- Duricryods**
Begin measuring depth below any O horizon. The cemented layer is present in ≥ 90% of each pedon.

3. **High amounts of organic carbon in the subsoil -------------- Humicryods**
These soils have ≥ 6.0% organic carbon in a layer ≥ 10 cm thick within the spodic horizon.

4. **A simple spodic horizon --- Haplocryods**

Descriptions of Great Groups of Cryods

Placocryods—These soils have a thin (≤ 2.5 cm) placic (cemented by iron and organic matter) horizon, typically within the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. In the United States, they are known to occur only in Alaska. They are thought to be rare elsewhere in the world. (Back to Cryods key)

Duricryods—These soils have a cemented horizon either within or below the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. The cemented horizon is considered to be ortstein if it is more than 2.5 cm thick and part of the spodic horizon. In the United States, these soils are known to occur in the State of Washington. They probably also occur in other cold regions of the world. (Back to Cryods key)

Profile of a Duricryod in a cold, forested area of Alaska. This soil has an ochric epipedon about 12 inches thick. Below this epipedon is a spodic horizon that consists of two parts. The black upper part (from about 12 to 20 inches) is cemented by iron and organic matter. It is ortstein. The lower, noncemented, reddish part extends from about 20 to 34 inches. Scale is in feet.

Return to Duricryods

Humicryods—These soils commonly have a thick O horizon over a very thin or intermittent albic (light-colored and leached) horizon, which overlies a dark-colored spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. They have a high content of organic carbon in the upper part of the spodic horizon. The vegetation commonly is coniferous forest or alpine tundra. In the United States, Humicryods occur mostly in southeast Alaska and in the mountains of Washington and Oregon. Some are in the higher mountains of the Northeast.

(Back to Cryods key)

Profile of a well drained Humicryod in Washington State. It has a dark brown ochric epipedon about 25 cm thick composed primarily of organic soil material. Below this epipedon is a light brown to gray albic horizon about 5 cm thick. Below this is a reddish brown spodic horizon that extends to a depth of about 60 cm. Hard phyllite bedrock is below 60 cm. Scale is in cm.

Return to Humicryods

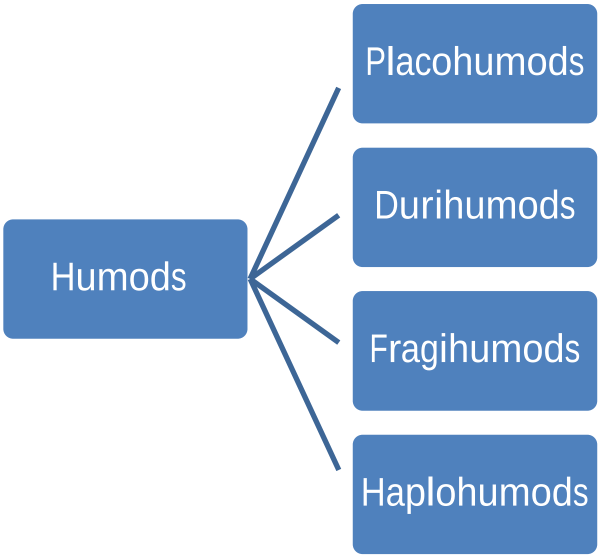
Haplocryods—These soils have horizons that are mostly thin but may be strongly contrasting. The base of the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) horizon is generally less than 50 cm below the mineral soil surface. Some Haplocryods have permafrost at varying depths below the spodic horizon, between 100 and 200 cm. Others have, below the spodic horizon, another sequum with an argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon. In the United States, Haplocryods occur mostly in Alaska and in the higher mountains of the West and Northeast. (Back to Cryods key)

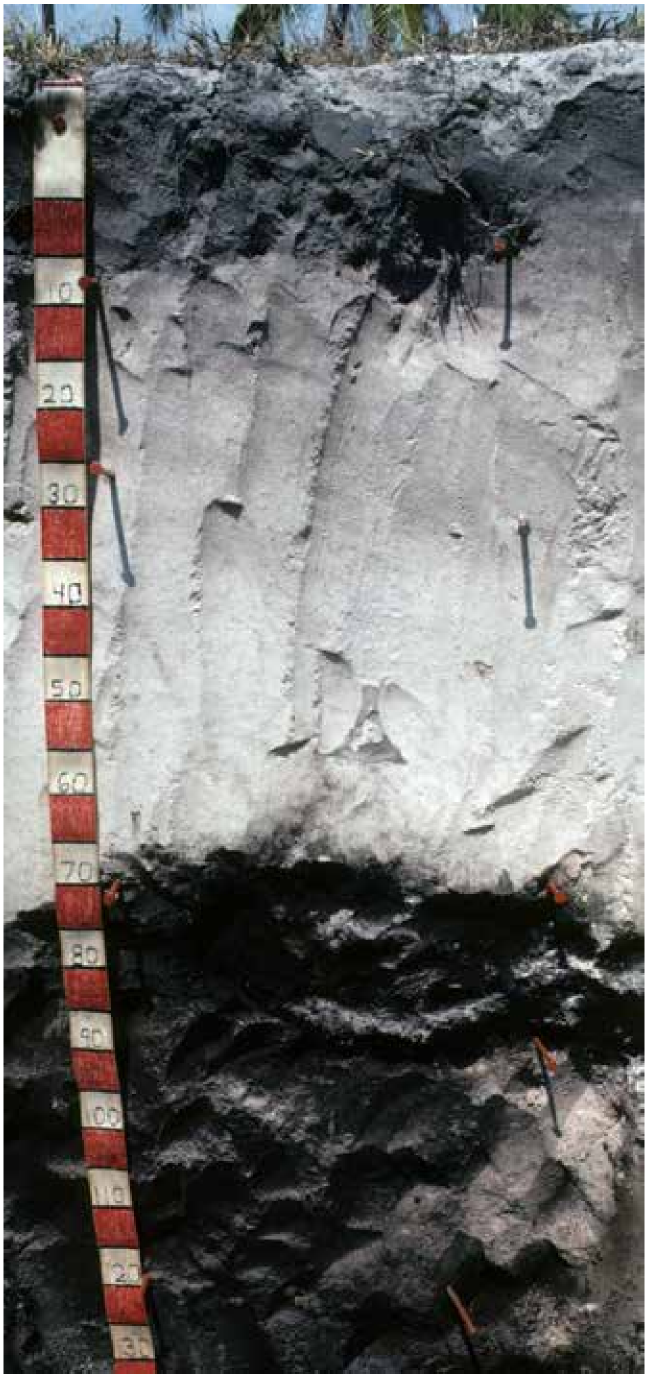
Humods Great Groups

Humods are the relatively freely drained Spodosols that have a large accumulation of organic carbon in the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. Undisturbed Humods may have either a thin, intermittent or a distinct, continuous albic (light-colored and leached) horizon over a spodic horizon, which in its upper part is nearly black and has reddish hue. The hue typically becomes yellower with increasing depth.

Humods formed predominantly in Pleistocene or Holocene deposits. In the United States, they developed mainly under a coniferous forest. In Western Europe, they are common in areas of sandy materials where heather (*Calluna vulgaris*) is, or used to be, a dominant plant. In tropical regions, most Humods supported rainforests.

Humods are not extensive in the United States. They are known to occur in northern New England and in the Pacific Northwest, mostly in small areas.





Profile of a Humod (specifically a Haplohumod). This soil has a thick albic horizon (white) underlain at a depth of about 70 cm by a spodic horizon with a high content of organic carbon. Scale is in cm.

Back to Humods

Key to Great Groups of Humods (Back to key to suborders)

Humods that have:

1. **A placic (cemented by iron and organic matter) horizon within a depth of 100 cm -- Placohumods**
   Begin measuring depth below any O horizon. The placic horizon is present in ≥ 50% of each pedon. By definition, a placic horizon in Spodosols is ≤ 2.5 cm thick.

2. **A cemented soil layer within a depth of 100 cm ------------- Durihumods**
   Begin measuring depth below any O horizon. The cemented layer is present in ≥ 90% of each pedon.

3. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm --- Fragihumods**
   Begin measuring depth below any O horizon.

4. **A favorable rooting depth of ≥ 100 cm ---------------------- Haplohumods**

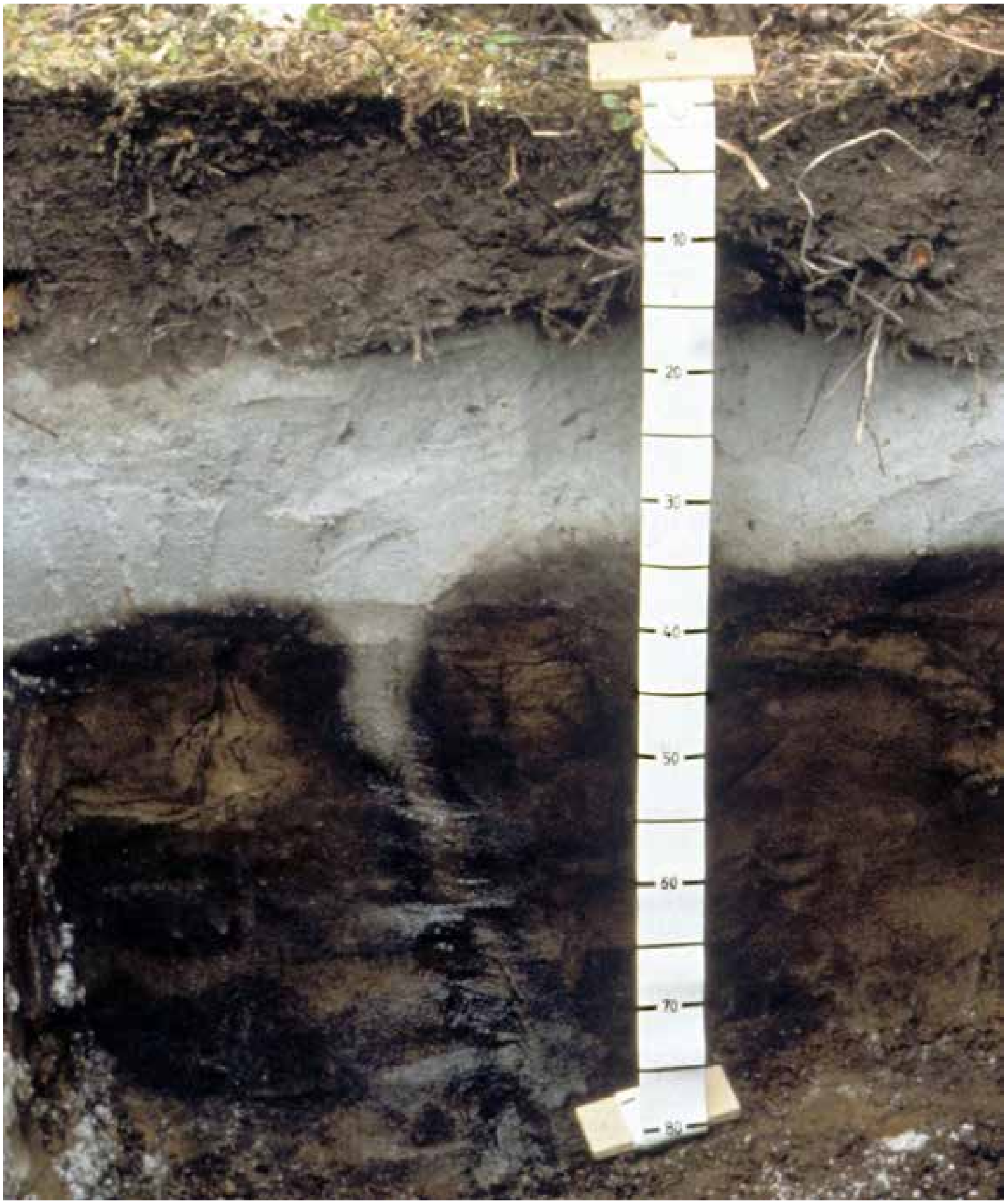
Descriptions of Great Groups of Humods

Placohumods—These soils have a thin (≤ 2.5 cm) placic (cemented by iron and organic matter) horizon within the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. They are probably rare in the world but are known to occur in eastern Canada and in parts of Western Europe, where their vegetation is, or used to be, heather. (Back to Humods key)

Durihumods—These soils have a layer that is cemented, commonly with sesquioxides and organic matter. The cemented horizon is considered to be ortstein if it is more than 2.5 cm thick and part of the spodic horizon. Some Durihumods have a duripan (layer cemented by silica). Durihumods are not common in the United States but occur in some areas in the Pacific Northwest and the Southeast. (Back to Humods key)

Fragihumods—These soils have a fragipan (firm and brittle but not cemented layer) below the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) horizon. They are not known to occur in the United States. (Back to Humods key)

Haplohumods—These soils have a favorable rooting depth (no root-restrictive layers) to ≥ 100 cm. They are commonly in cool to warm, moist coastal regions, although some are in inland areas at higher elevations. In the United States, these soils occur in the Northeast and the Pacific Northwest. They are also in the southeastern United States, particularly in areas of sandy deposits. In Western Europe, most of these soils at some time supported heather (*Calluna vulgaris*). If undisturbed, these soils generally have an umbric (humus-rich with low base saturation) epipedon and an albic (light-colored and leached) horizon overlying a spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon with reddish hue and a black upper subhorizon rich in organic carbon. Some of these soils, however, have an ochric (typically thin and/or light-colored) epipedon. (Back to Humods key)

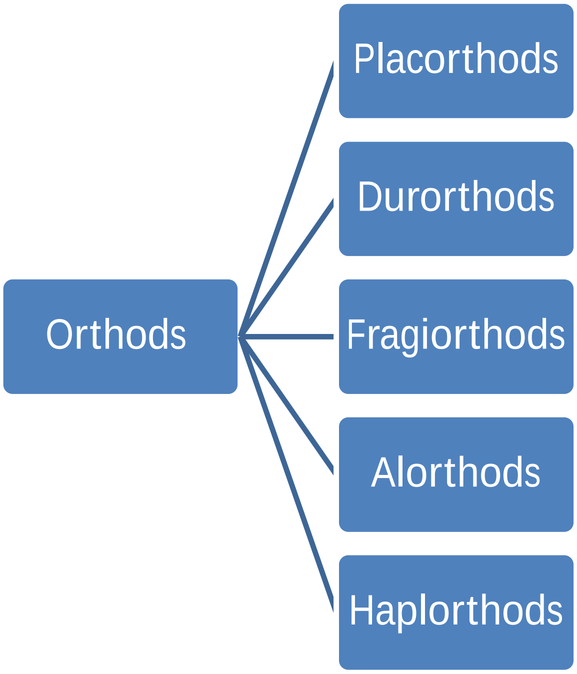


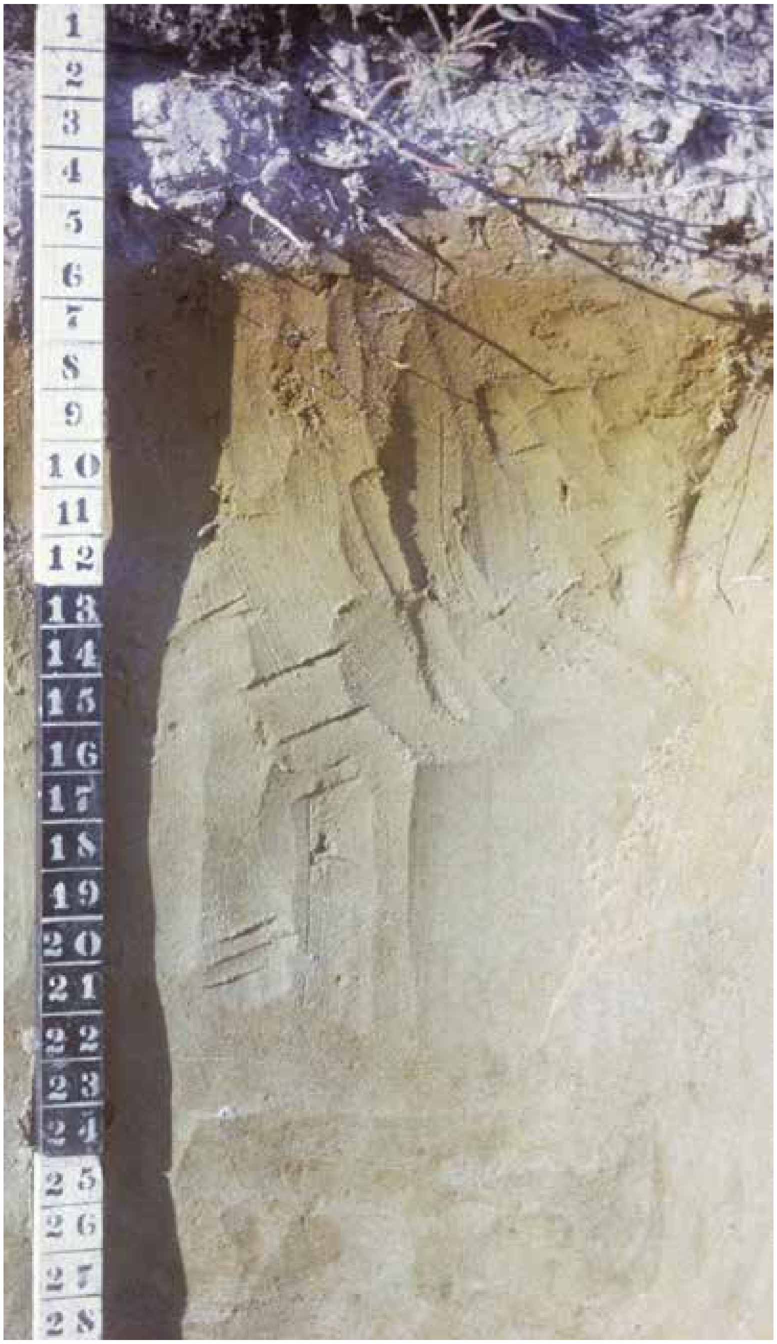
Profile of a sandy Haplohumod in New Zealand. This soil has an ochric epipedon consisting of a dark brown surface layer (about 15 cm thick) and an underlying light gray albic horizon (at depths of 15 to 35 cm). Below this epipedon is a black, organic carbon-rich spodic horizon that extends to a depth of about 70 cm. Scale is in cm.

Return to Haplohumods

Orthods Great Groups

Orthods are the relatively freely drained Spodosols that have a spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. These are the most common Spodosols in the northern parts of Europe and in the United States. They formed predominantly in coarse, acid Pleistocene or Holocene deposits under mostly coniferous forest vegetation. If undisturbed, Orthods typically have an O horizon, an albic (light-colored and leached) horizon, and a spodic subsoil horizon and may have a fragipan (firm and brittle but not cemented layer). Some of these soils, however, have been mixed by the roots of fallen trees or by animals and have a very thin albic horizon or no albic horizon. In cultivated areas, the albic horizon is commonly mixed with part of the spodic horizon. In the United Sates, Orthods are extensive in both the southeastern and northeastern parts, in the Great Lakes States, and in the mountains of the West.





Profile of an Orthod (specifically a Haplorthod). The albic horizon (white) extends from a depth of about 1 to 5 inches and is underlain by a reddish spodic horizon that extends to a depth of about 11 inches. Scale is in inches.

Back to Orthods

Key to Great Groups of Orthods (Back to key to suborders)

Orthods that have:

1. **A placic (cemented by iron and organic matter) horizon within a depth of 100 cm -- Placorthods**
   Begin measuring depth below any O horizon. The placic horizon is present in ≥ 50% of each pedon. By definition, a placic horizon in Spodosols is ≤ 2.5 cm thick.

2. **A cemented soil layer within a depth of 100 cm --------------- Durorthods**
   Begin measuring depth below any O horizon. The cemented layer is present in ≥ 90% of each pedon.

3. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm -- Fragiorthods**
   Begin measuring depth below any O horizon.

4. **A very low content of iron in the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) horizon -- Alorthods**
   These soils have < 0.10% iron (by ammonium oxalate) in ≥ 75% of the spodic horizon.

5. **A simple spodic horizon and a favorable rooting depth --- Haplorthods**

Descriptions of Great Groups of Orthods

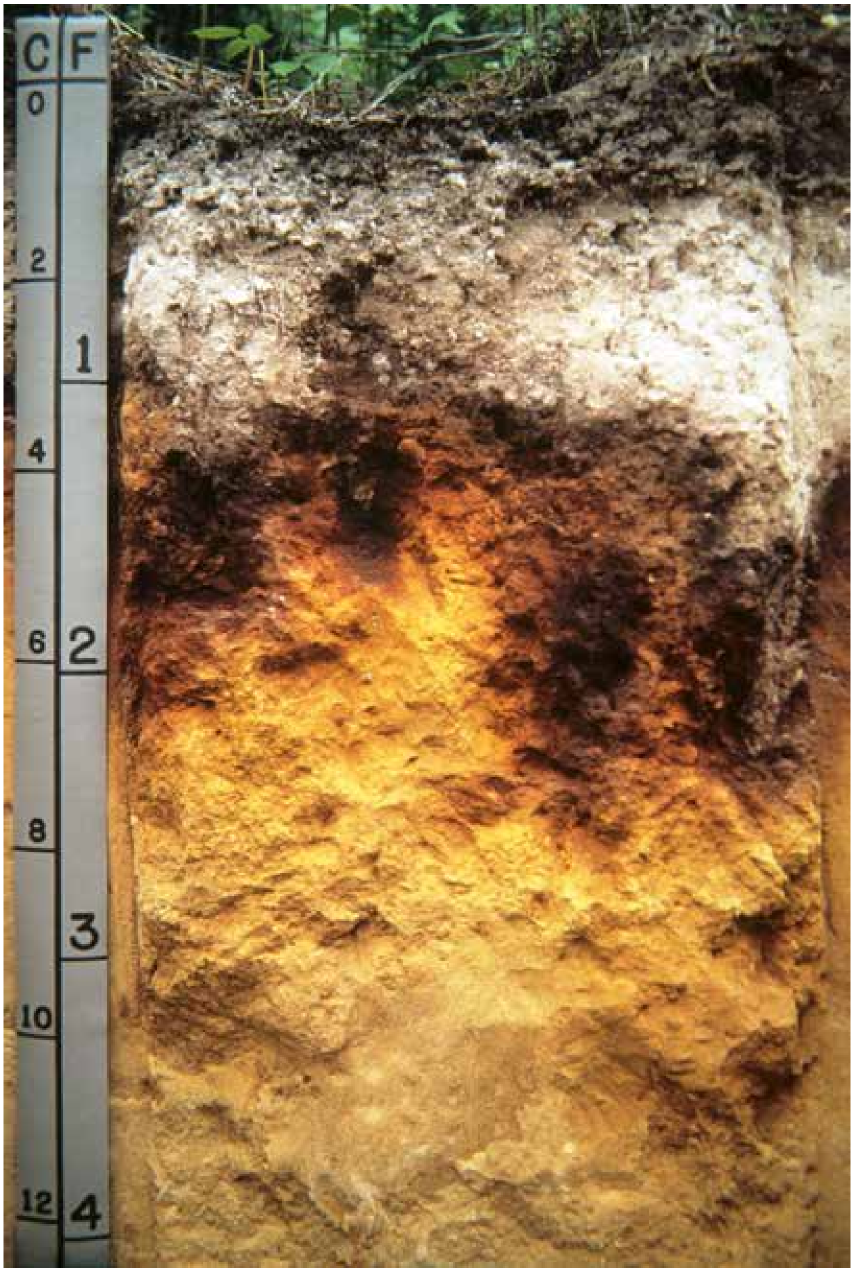
Placorthods—These soils have a thin (≤ 2.5 cm) placic (cemented by iron and organic matter) horizon within the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. They are not known to occur in the continental United States and are thought to be rare elsewhere in the world. (Back to Orthods key)

Profile of a sandy Placorthod in New Zealand. This soil has an ochric epipedon consisting of a dark brown surface layer (about 20 cm thick) and an underlying light gray albic horizon (ranging from about 5 to 15 cm in thickness). This epipedon has a smooth, wavy lower boundary. Directly below this is a dark yellowish brown spodic horizon about 5 to 10 cm thick, which also has a wavy boundary. At the base of this layer is a very thin (2 to 4 mm) placic horizon that has been cemented by accumulations of iron and organic matter. Below this is a slightly reddened, noncemented spodic horizon that has an accumulation of iron and aluminum. Scale is in cm.

Return to Placorthods

Durorthods—These soils have a layer that is cemented, commonly with combinations of iron, aluminum, and organic matter. The cemented horizon is considered to be ortstein if it is more than 2.5 cm thick and part of the spodic horizon. Some Durorthods may have a duripan (layer cemented by silica).

(Back to Orthods key)



Profile of a well drained, sandy Durorthod. This soil has an ochric epipedon consisting of a dark brown surface layer (about 2 inches thick) and a light gray albic horizon (between depths of 2 and 10 inches). A spodic horizon (dark brown) with a wavy boundary is directly below the albic horizon and extends to a depth of about 2 to 3 feet. The black parts of the spodic horizon are ortstein, cemented by iron and organic matter, and therefore restrict rooting.

Return to Durorthods

Fragiorthods—These soils have a fragipan (firm and brittle but not cemented layer) below the spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. They formed mainly in loamy deposits, but some formed in sandy deposits containing a considerable amount of fine and very fine sand. The fragipan may be thick, or it may have formed in the eluvial (E´) horizon of a lower sequum that overlies an argillic (clay accumulation) subsoil horizon. Generally, a lighter-colored eluvial horizon has developed above the fragipan, presumably because of the lateral movement of ground water. Trees growing on Fragiorthods are typically shallow-rooted and are sometimes blown down. When the trees are blown down, there is a mixing of soil horizons above the fragipan. As a consequence, many of these soils have a weakly expressed albic (light-colored and leached) horizon or no albic horizon or have a thin, intermittent albic horizon below part of the spodic horizon. A distinct microrelief is a normal feature, unless the soils have been smoothed by cultivation. In the United States, Fragiorthods are mostly in cold climates in the northern part of the country. (Back to Orthods key)

Alorthods—These soils have accumulations of aluminum that occur in relatively high amounts compared to accumulations of iron. They formed predominantly in sandy deposits. They have low amounts of iron accumulations either because of intensive leaching or because of parent materials that had a low iron content. Alorthods typically have a thick albic (light-colored and leached) horizon and an ochric (typically thin and/or light-colored) epipedon. They are more common in areas of warm climates than in cool environments. In the United States, they occur mainly in the Southeast.

(Back to Orthods key)

Haplorthods—These are the relatively freely drained Orthods that either have an albic (light-colored and leached) horizon and a spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon or, under cultivation, commonly have only a spodic horizon below an Ap horizon. The spodic horizon may rest on a lower sequum with an argillic (clay accumulation) subsoil horizon or kandic (very low cation-exchange capacity) subsoil horizon over relatively unaltered unconsolidated materials or on rock. Most Haplorthods have, or used to have, forest vegetation, mainly conifers but also hardwoods in some areas. A majority of these soils formed in sandy deposits or in materials weathered from sandstone or quartzite. (Back to Orthods key)

Profile of a well drained, sandy Haplorthod in Michigan. This soil has an ochric epipedon consisting of a dark brown surface layer (about 3 inches thick) and an underlying light gray albic horizon (between depths of 3 and about 12 inches). Note the irregular lower boundary of the albic horizon. Below the albic horizon is a brown and reddish yellow spodic horizon that extends to a depth of about 36 inches. Note the brown streaks extending into the reddish yellow material. The tongues of albic and spodic materials reflect the flow of water through the soil. Scale is in feet.

Return to Haplorthods

Ultisols Order

Ultisols are soils with low base-status and a clay-enriched subsoil.

General Characteristics

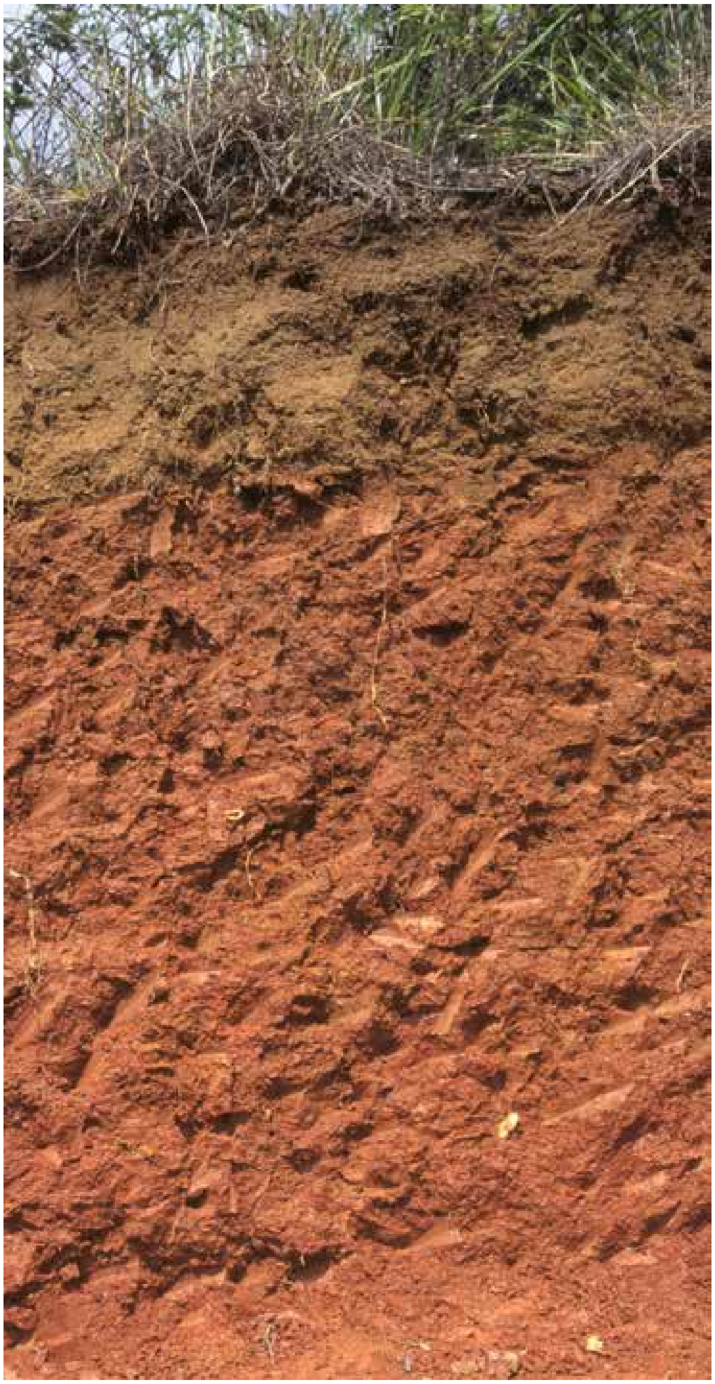
Typically, Ultisols have a surface layer consisting of an ochric (typically thin and/or light-colored) epipedon underlain by a clay-enriched subsoil. The subsoil is either an argillic (clay accumulation) horizon or, where the cation-exchange capacity is very low, a kandic horizon. The subsoil is commonly reddish in color due to coatings of iron oxides on mineral grains. Between the surface horizon and subsoil there is commonly a lighter-colored zone of leaching. All Ultisols have low base saturation, which makes them low in native fertility. A few wet Ultisols have an umbric (humus-rich with low base saturation) epipedon.

Environment and Processes

Ultisols mostly formed in warm, humid climates under forest vegetation. Commonly, they are in areas where there is a moisture deficit part of the year but where overall annual precipitation exceeds evaporation, conditions that result in a net leaching environment. Ultisols form in a wide range of parent materials, but generally the materials are acidic and infertile and do not provide a large amount of bases as they weather. Ultisols commonly are on relatively old landscapes that have undergone significant weathering so that the clay fraction in the subsoil tends to be dominated by low-activity minerals, such as kaolinite and iron and aluminum oxides. The fertility level of Ultisols is low, and plant nutrients are typically concentrated in the upper part of the profile (due to biocycling) and decrease in amount with increasing depth. The number of bases released by weathering is typically equal to or less than the number removed by leaching, and most of the bases are held in the vegetation and the upper soil horizons.

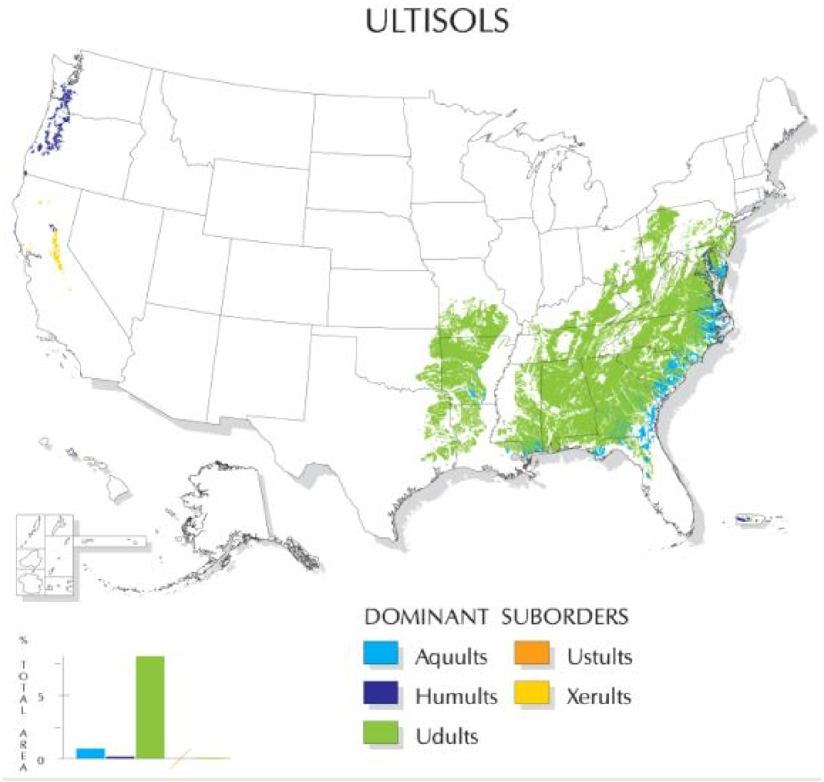
Location

Globally, Ultisols occupy about 8% of the ice-free land area. In the United States, Ultisols are mostly located in the Southeast, in the Piedmont, Appalachian Plateau, Ridge and Valley, and Coastal Plain physiographic regions, but also occur in the Pacific Northwest and in central California. Ultisols are also found in Southeast Asia, the Upper Amazon Basin in South America, and the Congo Basin in central Africa.

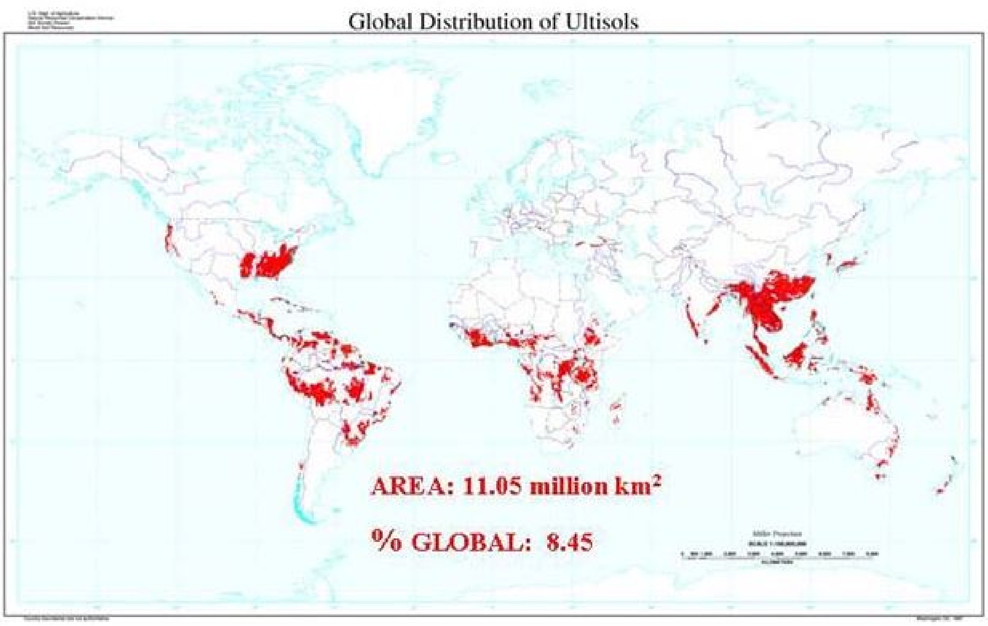


Profile of an Ultisol.

(Back to Key to Soil Orders)



Ultisols by suborder in the United States.



Global distribution of Ultisols.

Ultisols Suborders

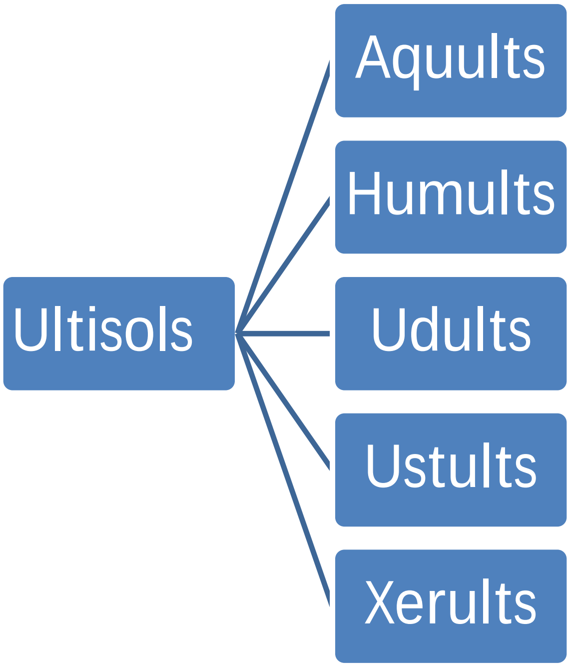
Classification of Ultisols

In the definitions of the suborders, emphasis is placed mostly on soil climate in the form of soil wetness (Aquults) and soil moisture regime (Udults, Ustults, and Xerults). One suborder (Humults) emphasizes the accumulation of organic carbon in the soil.

The great group level reflects a combination of important properties, including the presence of diagnostic horizons other than an argillic (clay accumulation) subsoil horizon and ochric (typically thin and/or light-colored) epipedon, an abrupt texture change to a slowly permeable layer, dark red colors, significant levels of plinthite (firm, iron oxide-rich concentration) in the subsoil, patterns of soil saturation, and a morphology that reflects advanced soil development on stable landforms.

The five suborders are:

1. Aquults—wet Ultisols (aquic conditions in the upper part)
2. Humults—Ultisols with a high amount of organic carbon accumulations in the subsoil
3. Udults—Ultisols of humid regions with well-distributed rainfall
4. Ustults—moderately dry Ultisols (limited moisture)
5. Xerults—moderately dry Ultisols (limited moisture that is supplied in winter and a Mediterranean-type climate)



Key to Suborders of Ultisols

Ultisols that have:

1. **A seasonal high water table within a depth of 50 cm ------------- Aquults**
   Evidence of a water table includes redoximorphic features (gray and red color patterns). See 12th edition of “Keys to Soil Taxonomy” for criteria regarding amount, color, and location of redoximorphic features. Begin measuring depth below any O horizon. Artificially drained sites are included in Aquults.

2. **High amounts of organic carbon in the subsoil ------------------- Humults**
   These soils have $\geq$ *0.9% organic carbon in the upper 15 cm of the subsoil, or they have* $\geq$ *12 kg/m*^{2} *in the upper 100 cm of the profile.*

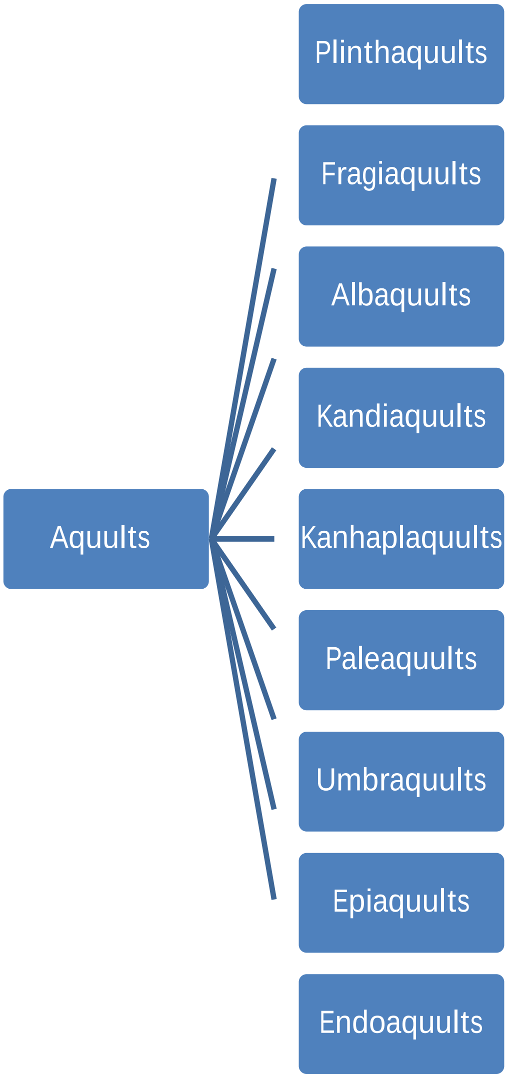
3. **Seasonally well-distributed precipitation ------------------------------ Udults**
   These soils have a udic soil moisture regime.

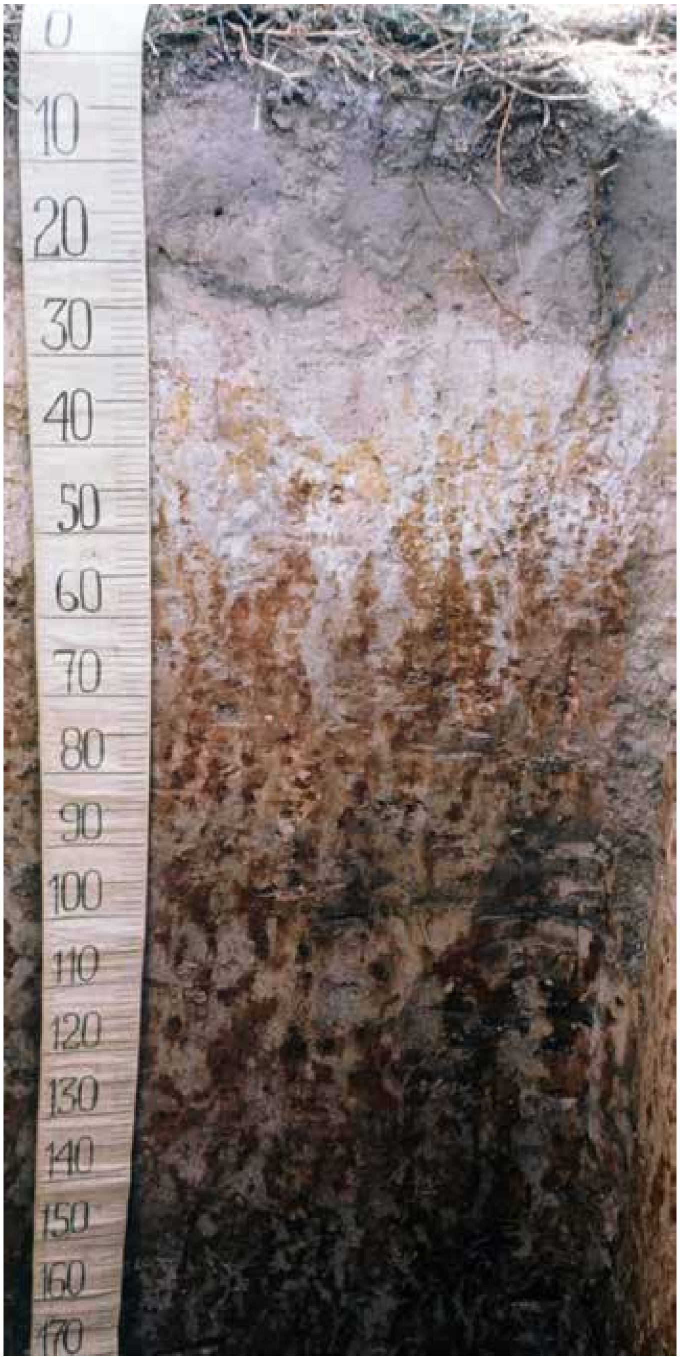
4. **Somewhat limited soil moisture available for plant growth ----- Ustults**
   These soils have an ustic soil moisture regime. Moisture is limited, but available, during portions of the growing season.

5. **A Mediterranean-type climate --- Xerults**
   These soils have a xeric soil moisture regime (cool and moist in winter and warm and dry in summer).

Aquults Great Groups

Aquults are the Ultisols in wet areas where ground water is very close to the surface during part of each year, usually in winter and spring at middle latitudes, and is frequently deep at other times. Saturation persists long enough during the year for the soil to become devoid of oxygen in the upper part (aquic conditions). These soils are mostly grayish or olive in the subsoil and formed mainly in alluvium and marine deposits that are Pleistocene in age or older. Aquults are extensive on the coastal plains in the United States, particularly along the Atlantic Ocean and the Gulf of Mexico. Their slopes are gentle. Most of these soils had, and many still have, forest vegetation. Aquults have an ochric (typically thin and/or light-colored) or umbric (humus-rich with low base saturation) epipedon and an argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon. Some have a fragipan (firm and brittle but not cemented layer), and others have plinthite (firm, iron oxide-rich concentration) in or below the argillic or kandic horizon.





Profile of an Aquult (specifically a Plinthaquult) in Venezuela. Some of the red bodies in the subsoil are plinthite. Scale is in cm.

Back to Aquults

Key to Great Groups of Aquults (Back to key to suborders)

Aquults that have:

1. **Plinthite making up ≥ 50% of a layer within a depth of 150 cm --- Plinthaquults**
   Begin measuring depth below any O horizon. Plinthite is a firm, iron oxide-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles.

2. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm -- Fragiaquults**
   Begin measuring depth below any O horizon.

3. **An abrupt increase in clay content to the subsoil horizon --- Albaquults**
   See "abrupt texture change" definition for specific criteria. Also, the K_{sat} class must be moderately low or lower in the subsoil (most likely to be met if the texture is sandy clay, silty clay, or clay). Albaquults may have either an argillic or kandic subsoil horizon.

4. **A kandic (very low cation-exchange capacity) horizon and a clay content that does not decrease significantly within a depth of 150 cm --- Kandiaquults**
   Clay content must not decrease by ≥ 20% of the maximum in the kandic horizon, unless clay depletions (gray areas where clay and iron have been lost) are present in the layer and the clay content increases again by ≥ 3% below. Kandiaquults cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

5. **A kandic (very low cation-exchange capacity) horizon and a significant decrease in clay content within a depth of 150 cm --- Kanhaplaquults**
   Begin measuring depth below any O horizon.

6. **A clay content that does not decrease significantly within a depth of 150 cm --- Paleaquults**
   Clay content must not decrease by ≥ 20% of the maximum in the argillic horizon, unless clay depletions (gray areas where clay and iron have been lost) are present in the layer and the clay content increases again by ≥ 3% below. Paleaquults cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

7. **A thick, dark-colored, humus-rich, surface horizon ------- Umbraquults**
   These soils have either a mollic (rich in humus and bases) or umbric (humus-rich with low base saturation) epipedon.

8. **Episaturation (perched water table) -------------------------------- Epiaquults**
9. **Endosaturation (saturated throughout the profile) --------- Endoaquults**

Descriptions of Great Groups of Aquults

Plinthaquults—These soils have plinthite (firm, iron oxide-rich concentration) that either forms a continuous phase or constitutes more than half the matrix of some subhorizon within a depth of 150 cm. These soils are mostly in intertropical areas and constitute a small area of Puerto Rico. (Back to Aquults key)

Profile of a poorly drained Plinthaquult in Vietnam. Note the water table below a depth of 120 cm. During wet periods of the year, the water table is near the surface. The red material below a depth of about 60 cm is plinthite. Scale is in 10-cm increments.

Return to Plinthaquults

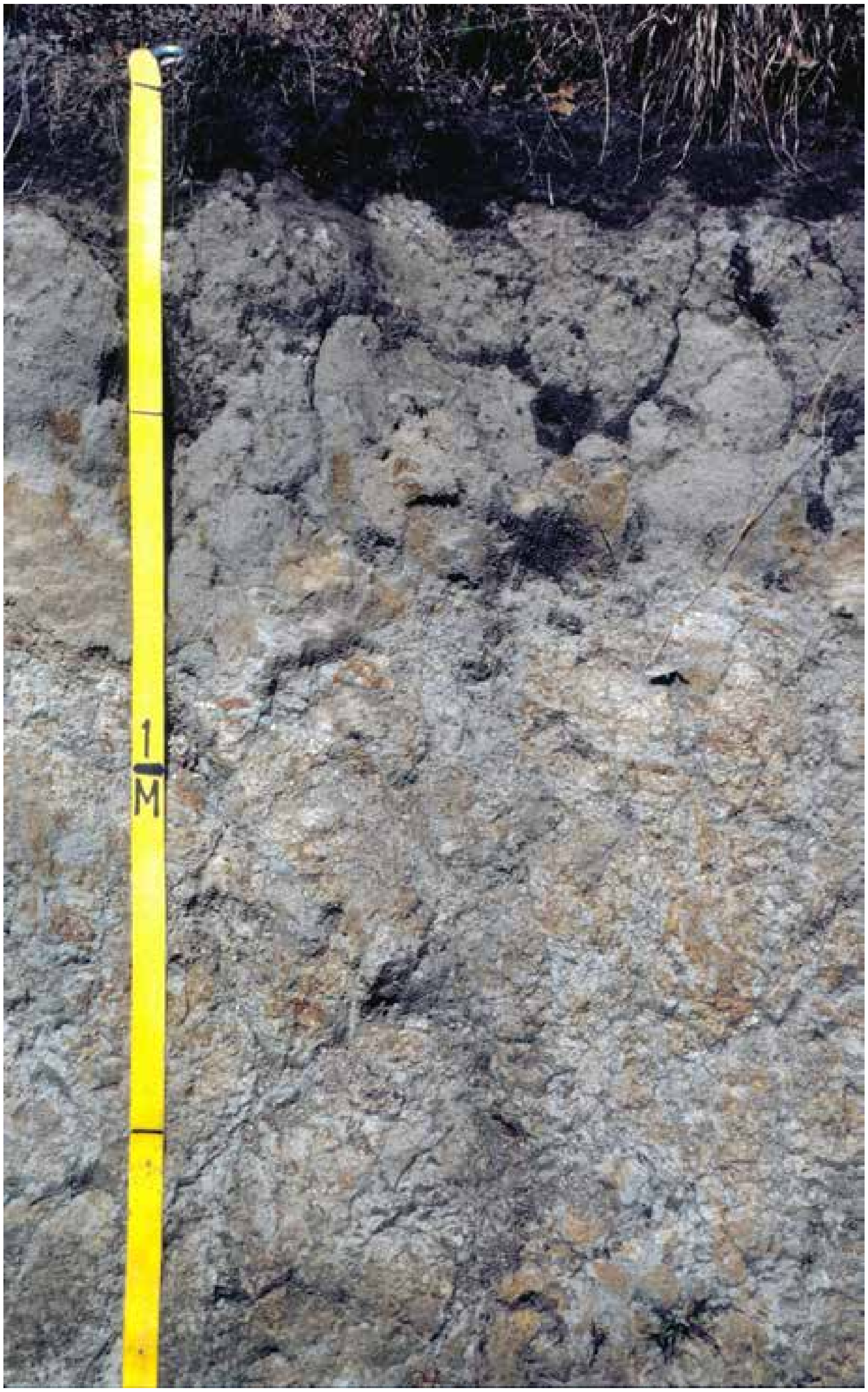
Fragiaquults—These soils have a fragipan (firm and brittle but not cemented layer) with an upper boundary within a depth of 100 cm. Normally, the fragipan lies below the argillic (clay accumulation) or kandic (very low cation-exchange capacity) horizon. In a few of the soils, however, it may be in the lower part of the argillic or kandic subsoil horizon. (Back to Aquults key)

Albaquults—These soils have a marked increase in percentage of clay at an abrupt boundary at the top of the argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon. The subsoil horizon generally is clayey and has moderately low or lower hydraulic conductivity. In most years water is perched for short duration above the argillic or kandic horizon prior to complete soil saturation. Slopes are nearly level, and draining the soils is difficult. In the southeastern United States, these soils formed mostly in acid, late-Pleistocene sediments and are on low marine or stream terraces. Most have a season when the upper horizons are dry. Some of the Albaquults in the United States have been cleared for grazing or cropping, but many are forested. (Back to Aquults key)

Kandiaquults—These soils have a kandic (very low cation-exchange capacity) horizon and a clay distribution in which the percentage of clay does not decrease from its maximum amount by as much as 20 percent within a depth of 150 cm. Kandiaquults are not known to occur in the United States. The great group is provided for use in other parts of the world. (Back to Aquults key)

Kanhaplaquults—These soils have a kandic (very low cation-exchange capacity) horizon in which clay content decreases significantly within a depth of 150 cm. They have a thin or moderately thick zone of maximum clay content. Kanhaplaquults are not known to occur in the United States. The great group is provided for use in other parts of the world. (Back to Aquults key)

Paleaquults—These soils have an argillic (clay accumulation) subsoil horizon and a percentage of clay that does not decrease from its maximum amount by as much as 20 percent within a depth of 150 cm. Paleaquults formed mostly on mid-Pleistocene or older land surfaces, on high marine or river terraces, or on old deltas. They are of large extent in the southeastern United States. The natural vegetation consisted of forest plants, mostly water-tolerant conifers or hardwood trees. (Back to Aquults key)



Profile of a poorly drained, clayey Paleaquult in Georgia. It has a humus-rich, black ochric epipedon a few inches thick. Below this epipedon is an argillic horizon that is predominantly gray with reddish yellow redoximorphic features. The right side of the profile has been smoothed. Scale is in half-meter increments.

Return to Paleaquults

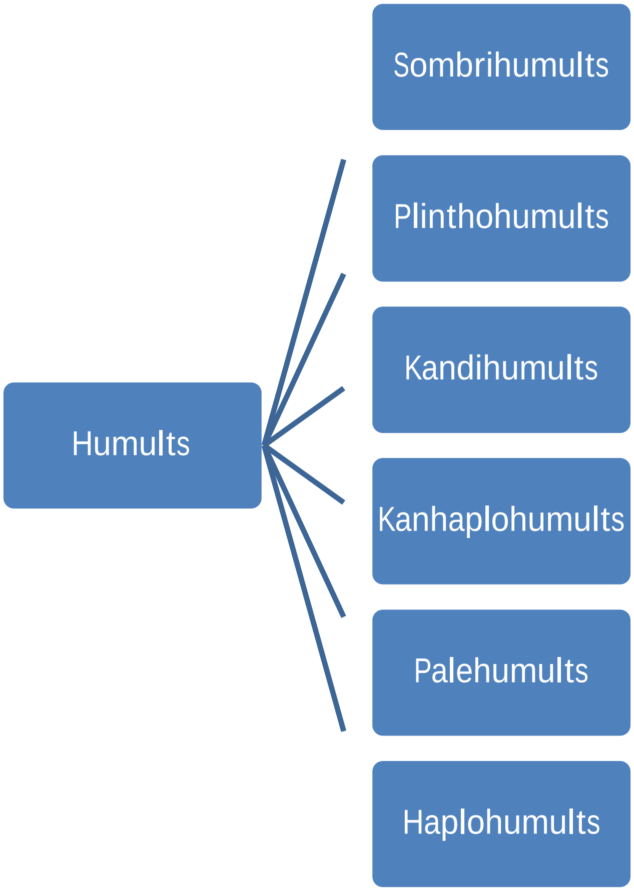
Umbraquults—These soils commonly have an umbric (humus-rich with low base saturation) epipedon, but a few with high base-status in the upper part of the soil may have a mollic (rich in humus and bases) epipedon. Umbraquults are among the wettest of the Aquults, and their argillic (clay accumulation) subsoil horizon is not as strongly developed as that of other Aquults. Umbraquults have a thin or moderately thick zone of maximum clay content. The natural vegetation consisted mostly of water-tolerant trees and herbs (hydrophytic vegetation). (Back to Aquults key)

Epiaquults—These soils have water perched on a less permeable layer, commonly an argillic subsoil horizon. Slopes generally are nearly level. Before cultivation, most Epiaquults supported either deciduous broadleaf or coniferous forest. (Back to Aquults key)

Endoaquults—These soils have a ground-water level that fluctuates from the soil surface to depths that may exceed 2 meters. Generally, they are nearly level. Before cultivation, most Endoaquults supported either deciduous broadleaf or coniferous forest plants. (Back to Aquults key)

Humults Great Groups

Humults are the freely drained, humus-rich Ultisols of mid or low latitudes. At mid latitudes they are mostly dark colored, but at low latitudes their content of humus is not necessarily reflected by color. These soils are mainly in mountainous areas that have high amounts of rainfall but also have a moisture deficiency during some season. Most of the Humults in the United States formed in basic rock on surfaces that are late Pleistocene in age or older. Slopes commonly are strong. If the soils are cultivated, the subsoil horizon may be exposed at the surface due to erosion. To keep the eroded and uneroded soils in the same classification, the suborder criteria were written in terms of the carbon content of the whole soil or the argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon. The natural vegetation was mostly coniferous forest plants at mid latitudes and rainforests at low latitudes.



Profile of a Humult (specifically a Palehumult) in Brazil. This soil has an ochric epipedon about 25 cm thick underlain by a thick argillic subsoil horizon that extends to a depth of more than 150 cm. The argillic horizon has a relatively high content of organic carbon.

Back to Humults

Key to Great Groups of Humults (Back to key to suborders)

Humults that have:

1. **A sombric subsoil horizon (dark layer in which organic matter has accumulated) within a depth of 100 cm -------------------- Sombrihumults**
   Begin measuring depth below any O horizon.

2. **Plinthite making up ≥ 50% of a layer within a depth of 150 cm -- Plinthohumults**
   Begin measuring depth below any O horizon. Plinthite is a firm, iron oxide-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles.

3. **A kandic (very low cation-exchange capacity) horizon and a clay content that does not decrease significantly within a depth of 150 cm -- Kandihumults**
   Clay content must not decrease by ≥ 20% of the maximum in the kandic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below. Kandihumults cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

4. **A kandic (very low cation-exchange capacity) horizon and a significant decrease in clay content within a depth of 150 cm --- Kanhaplohumults**
   Begin measuring depth below any O horizon.

5. **An argillic (clay accumulation) subsoil horizon and a clay content that does not decrease significantly within a depth of 150 cm -- Palehumults**
   Clay content must not decrease by ≥ 20% of the maximum in the argillic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below. Palehumults cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

6. **An argillic (clay accumulation) horizon and a significant decrease in clay content within a depth of 150 cm ------------------------ Haplohumults**
   Begin measuring depth below any O horizon.

Descriptions of Great Groups of Humults

Sombrihumults—These soils have a sombric subsoil horizon (dark layer in which organic matter has accumulated) that has its upper boundary within a depth of 100 cm. They are not known to occur in the United States. The great group is provided for use in other parts of the world. (Back to Humults key)

Profile of a clayey Sombrihumult in Rwanda. It has an umbric epipedon about 35 cm thick that is underlain by a lighter-colored argillic horizon (at depths of 35 to 90 cm). Below a depth of about 90 cm is a dark-colored sombric horizon. Scale is in 5-cm increments.

Return to Sombrihumults

Plinthohumults—These soils have plinthite (firm, iron oxide-rich concentration) that forms a continuous phase in, or constitutes more than half the volume of, one or more horizons within a depth of 150 cm. They are not known to occur in the United States. The great group has been provided for use in other parts of the world. (Back to Humults key)

Kandihumults—These soils have a kandic (very low cation-exchange capacity) subsoil horizon and a clay distribution in which the percentage of clay does not decrease from its maximum amount by as much as 20% within a depth of 150 cm. In the United States, a small extent of Kandihumults occurs in California and Hawaii. (Back to Humults key)

Kanhaplohumults—These soils have a kandic (very low cation-exchange capacity) subsoil horizon and have a clay distribution in which the percentage of clay decreases significantly within a depth of 150 cm. They have a thin to moderately thick zone of maximum clay content. Kanhaplohumults are of very small extent worldwide. In the United States, they are known to occur only in California and Hawaii. (Back to Humults key)

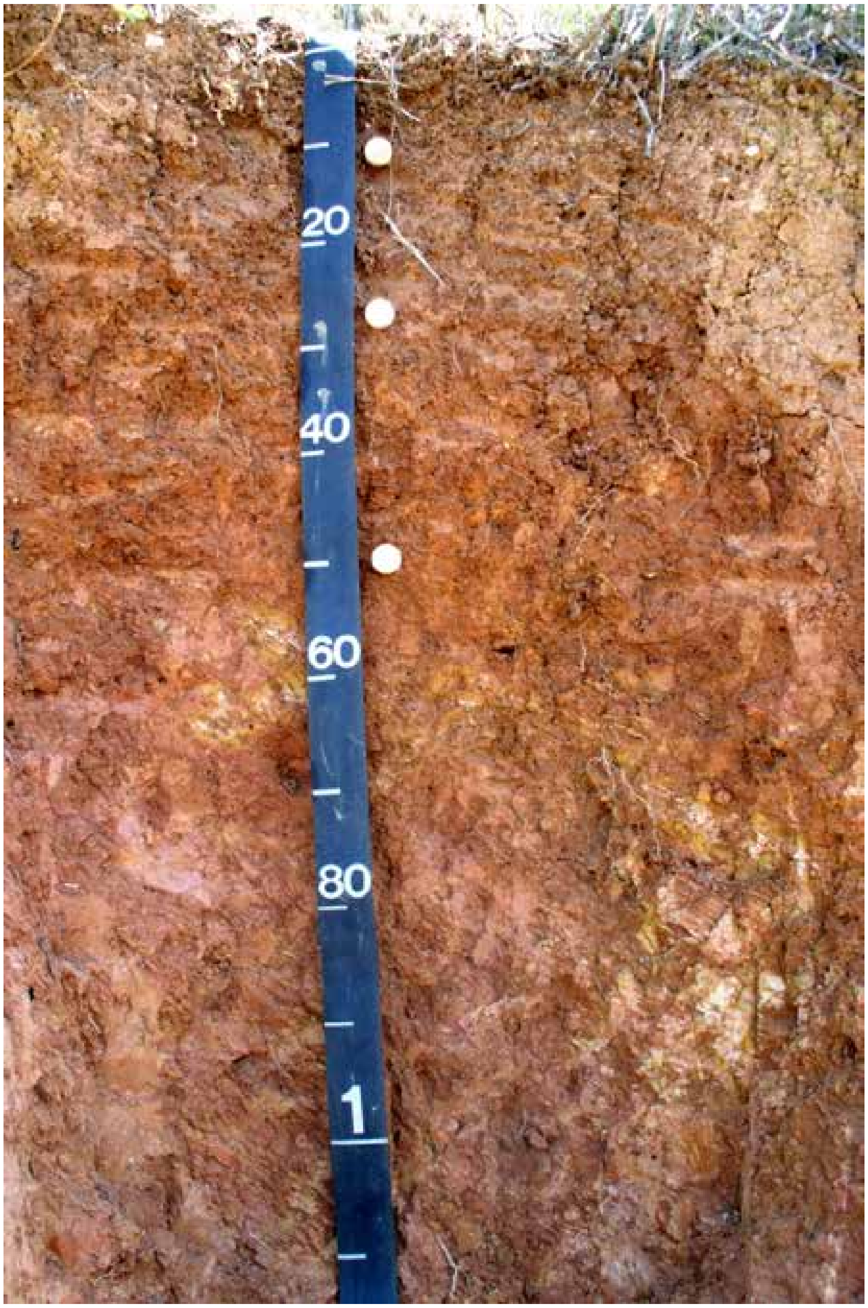
Palehumults—These soils are on old stable surfaces. In these soils, the percentage of clay does not decrease from its maximum amount by as much as 20% within a depth of 150 cm or the layer in which the clay percentage decreases has at least 5% of the volume consisting of skeletans (ped surfaces stripped of clay) and there is at least a 3% increase in clay content below this layer. These soils have an argillic (clay accumulation) subsoil horizon. They are moderately extensive and occur mostly in California, western Oregon and Washington, and Hawaii. Like other Humults in the United States, they formed mostly in material weathered from basic rocks or in alluvium derived from basic rocks. Most Palehumults have had forest vegetation, and many still have forest vegetation. (Back to Humults key)

Profile of a well drained, loamy Palehumult in Thailand. It has a dark brown umbric epipedon 25 cm thick underlain by a thick reddish brown argillic horizon. At a depth of about 100 cm is a lithologic discontinuity within the argillic horizon to material with a high content of gravel.

Return to Palehumults

Haplohumults—These soils have an argillic (clay accumulation) subsoil horizon with a significant decrease in clay content within a depth of 150 cm. They have a thin to moderately thick zone of maximum clay content. The Haplohumults in the United States are mainly in mountains close to the Pacific Ocean and have gentle to very steep slopes. Most Haplohumults have coniferous forest vegetation. Their content of organic carbon commonly is high relative to that of most other kinds of soil. Some of these soils have an umbric (humus-rich with low base saturation) epipedon, but many have a color value and chroma higher than the value and chroma of umbric epipedons.

(Back to Humults key)

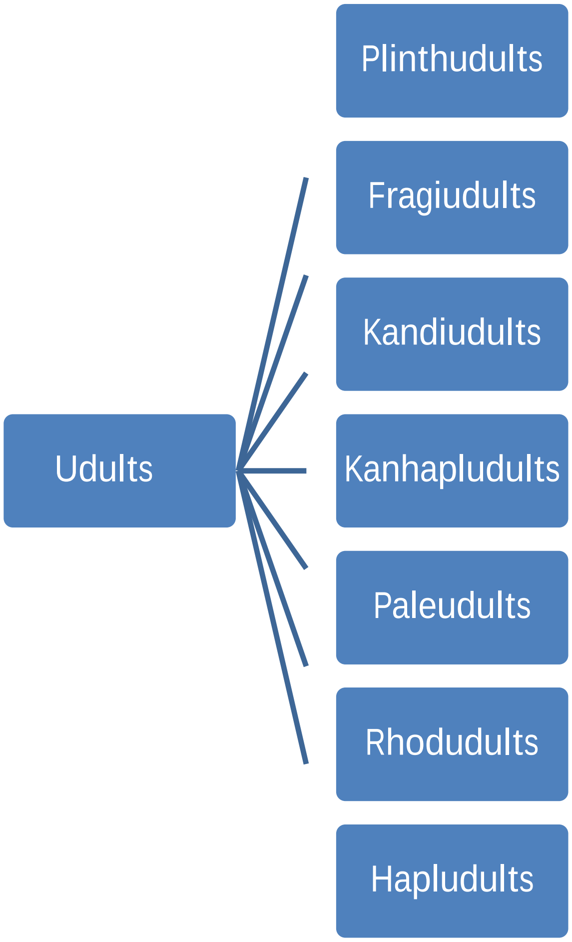


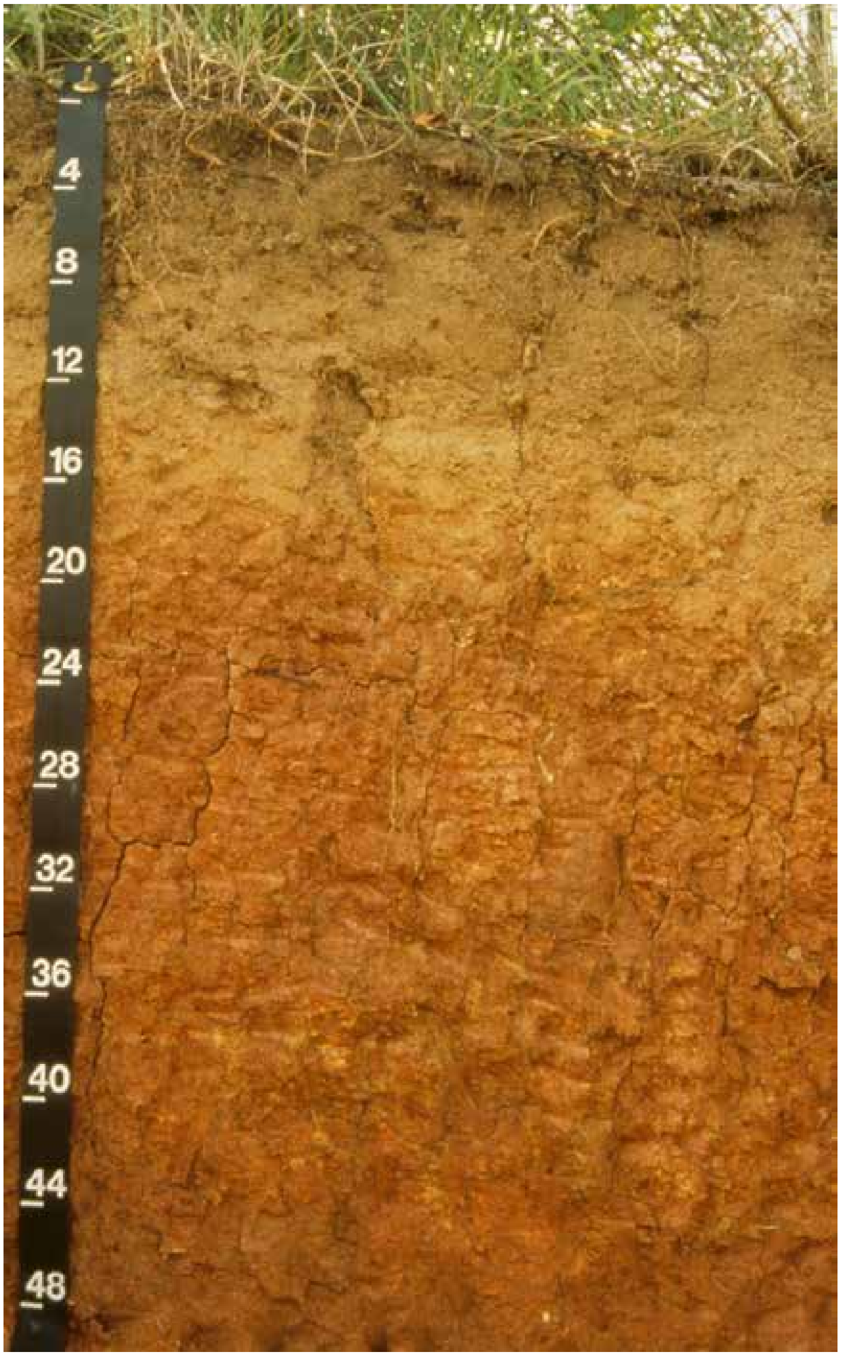
Profile of a moderately well drained, clayey Haplohumult in Puerto Rico. This soil has an ochric epipedon about 10 cm thick underlain by a red clayey argillic horizon that extends to a depth of about 50 cm. Below 50 cm, it consists of loamy material weathered from volcanic rock. This soil is in an area of fairly high precipitation and has a relatively high content of organic carbon in the surface and subsoil layers. Scale is in cm.

Return to Haplohumults

Udults Great Groups

Udults are the more or less freely drained, humus-poor Ultisols in humid areas with seasonally well-distributed precipitation (udic moisture regime). Most have light-colored upper horizons and commonly a grayish horizon that rests on a yellowish brown to reddish argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon. A few that developed from basic rocks have a dark brown or reddish brown surface horizon that rests on a dark red or dusky red argillic or kandic horizon. Some have a fragipan (firm and brittle but not cemented layer) or plinthite (firm, iron oxide-rich concentration), or both, in or below the argillic or kandic horizon. Udults developed in sediments and on surfaces that range in age from late Pleistocene to Pliocene or possibly older. Many are cultivated, either with the use of soil amendments or in a system in which they are cropped for a very few years and then returned to forest to allow nutrient recycling. Most of these soils have or had forest vegetation, but some support a savanna that probably resulted from human-caused fire activity.





Profile of a Udult (specifically a Kandiudult) in North Carolina. This soil has an ochric epipedon about 12 inches thick underlain by a reddish yellow kandic horizon that extends below the base of the photo. Scale is in inches.

Back to Udults

Key to Great Groups of Udults (Back to key to suborders)

Udults that have:

1. **Plinthite making up ≥ 50% of a layer within a depth of 150 cm --- Plinthudults**
Begin measuring depth below any O horizon. Plinthite is a firm, iron oxide-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles.

2. **A fragipan (firm and brittle but not cemented layer) within a depth of 100 cm -- Fragiudults**

3. **A kandic (very low cation-exchange capacity) horizon and a clay content that does not decrease significantly within a depth of 150 cm --- Kandiudults**
Clay content must not decrease by ≥ 20% of the maximum in the kandic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below. Kandiudults cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

4. **A kandic (very low cation-exchange capacity) horizon and a significant decrease in clay content within a depth of 150 cm --- Kanhapludults**
Begin measuring depth below any O horizon.

5. **An argillic (clay accumulation) subsoil horizon and a clay content that does not decrease significantly within a depth of 150 cm --- Paleudults**
Clay content must not decrease by ≥ 20% of the maximum in the argillic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below. Paleudults cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

6. **Both a dark surface layer and a dark, reddish argillic (clay accumulation) subsoil horizon ------------------------------------ Rhodudults**
The surface layer and subsoil have moist value of ≤ 3. The hue of the argillic horizon is mostly 2.5YR or redder and its value increases no more than 1 unit when dry. The argillic color requirement applies to a depth of 100 cm, or to the entire argillic horizon if thinner. Begin measuring depth below any O horizon.

7. **An argillic (clay accumulation) horizon and a significant decrease in clay content within a depth of 150 cm ---------------------------- Hapludults**
Begin measuring depth below any O horizon.

Descriptions of Great Groups of Udults

Plinthudults—These soils are the more or less freely drained Udults that have a large amount of plinthite (firm, iron oxide-rich concentration) in the subsoil. They are mainly in intertropical regions and, in some areas, are extensive. They are not known to occur in the United States. (Back to Udults key)

Fragiudults—These soils have a fragipan (firm and brittle but not cemented layer) within a depth of 100 cm. They formed mainly in loamy alluvium or in residuum. The fragipan commonly has an upper boundary between 50 and 100 cm below the mineral soil surface. Ground water is perched above the pan at some period during the year, and many of the soils have thick clay depletions (gray areas where clay and iron have been lost) near the top of the fragipan and in vertical seams between structural units. Fragiudults are principally found on gentle slopes throughout the southeastern United States. The vegetation was a forest of either mixed conifers or broadleaf deciduous trees. (Back to Udults key)

Kandiudults—These soils have a kandic (very low cation-exchange capacity) subsoil horizon and a clay distribution in which the percentage of clay does not decrease from its maximum amount by as much as 20% within a depth of 150 cm, or the layer in which the clay percentage decreases has at least 5% of the volume consisting of skeletans (ped surfaces stripped of clay) and there is at least a 3% (absolute) increase in clay content below this layer. Kandiudults are mostly found on older geomorphic surfaces of the southeastern Coastal Plain of the United States. (Back to Udults key)

Profile of a Kandiudult in Brazil. This soil has an ochric epipedon about 30 cm thick underlain by a red kandic horizon that extends below the base of the photo. Scale is in cm.

Return to Kandiudults

Kanhapludults—These soils have a kandic (very low cation-exchange capacity) subsoil horizon. They are less than 150 cm deep, or the kandic horizon has a clay distribution in which the clay content decreases significantly within a depth of 150 cm. These soils have a thin to moderately thick zone of maximum clay content. The natural vegetation consisted of forest plants. Many of the soils have been cleared and are used as cropland or pasture. Kanhapludults are commonly found in the Southeastern Piedmont of the United States. (Back to Udults key)

Profile of a Kanhapludult in Georgia. It has an ochric epipedon about 12 inches thick underlain by a reddish yellow kandic horizon that extends to a depth of about 36 inches. Below the kandic horizon is weathered granitic saprolite. Scale is in feet.

Return to Kanhapludults

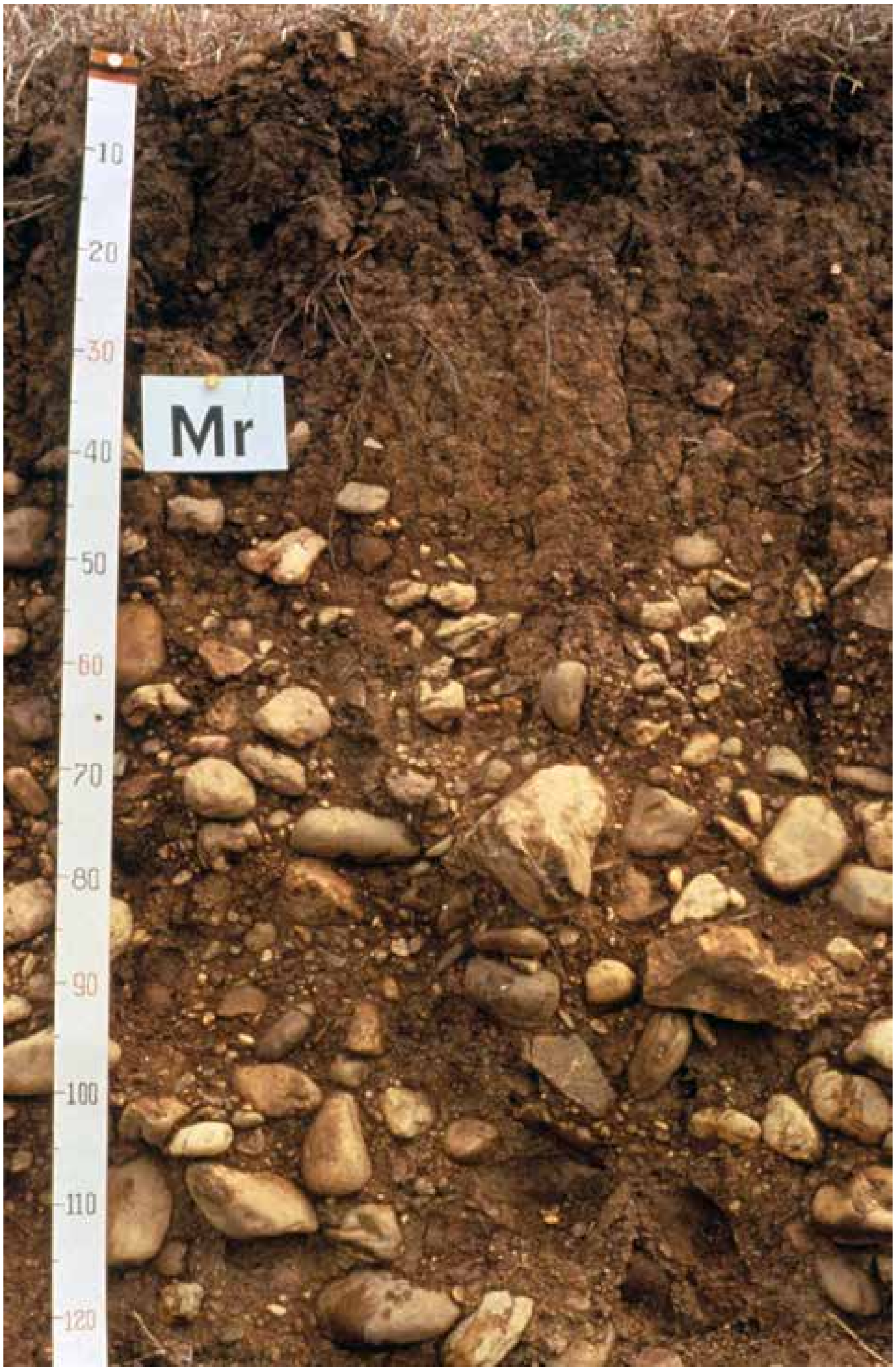
Paleudults—These soils are on very old, stable land surfaces. They have a thick argillic (clay accumulation) subsoil horizon. They have a clay distribution in which the percentage of clay does not decrease from its maximum amount by as much as 20% within a depth of 150 cm, or the layer in which the clay percentage decreases has at least 5% of the volume consisting of skeletans (ped surfaces stripped of clay) and there is at least a 3% (absolute) increase in clay content below this layer. Slopes generally are gently sloping or nearly level. The natural vegetation consisted of forest plants, mostly hardwoods or mixed conifers and hardwoods. Many of these soils have been cleared and are used as cropland or pasture. Paleudults are extensive in the southeastern and middle Atlantic areas of the United States. (Back to Udults key)

Profile of a Paleudult in Alabama. The ochric epipedon consists of a darkened surface layer and an underlying grayish brown layer that extends to a depth of about 10 inches. This epipedon is underlain by a thick, red argillic horizon that extends beyond the base of the photo. Scale is in inches.

Return to Paleudults

Rhodudults—These soils have a dark-colored epipedon and an argillic (clay accumulation) subsoil horizon with dark reddish colors throughout the upper part. They have a thin or moderately thick zone of maximum clay content. Rhodudults formed under forest vegetation and commonly from basic rocks or sediments. They tend to have more total phosphorus than most other Udults. They also tend to be less erosive. Rhodudults range from nearly level to very steep. Most of these soils formed in sediments or on surfaces dating to the latter half of the Pleistocene (Illinoian or Wisconsinan). Where slopes are suitable, most of the soils are used as cropland. In many of the soils, the plow layer includes material that was part of the argillic horizon. (Back to Udults key)

Hapludults—These soils have an argillic (clay accumulation) subsoil horizon and a clay distribution that decreases significantly within a depth of 150 cm. They have a thin or moderately thick zone of maximum clay content. Most of the soils formed in areas of acid rocks or sediments on surfaces that are at least Pleistocene in age. Where the soils are not cultivated, the vegetation consists of hardwood trees or conifers. Hapludults are extensive in the southeastern United States, in the mid Atlantic States, and on the Coastal Plain along the Gulf of Mexico in the southern States east of the Mississippi River. Slopes generally are gently sloping to steep, but a few of the soils on the lowest part of the Coastal Plain are nearly level. (Back to Udults key)



Profile of a well drained, cobbly Hapludult in Thailand. It has a humus-rich ochric epipedon about 20 cm thick underlain by an argillic horizon that extends to a depth of about 50 cm. Note the many rounded cobbles and gravel in the alluvial parent material below the argillic horizon. Scale is in cm.

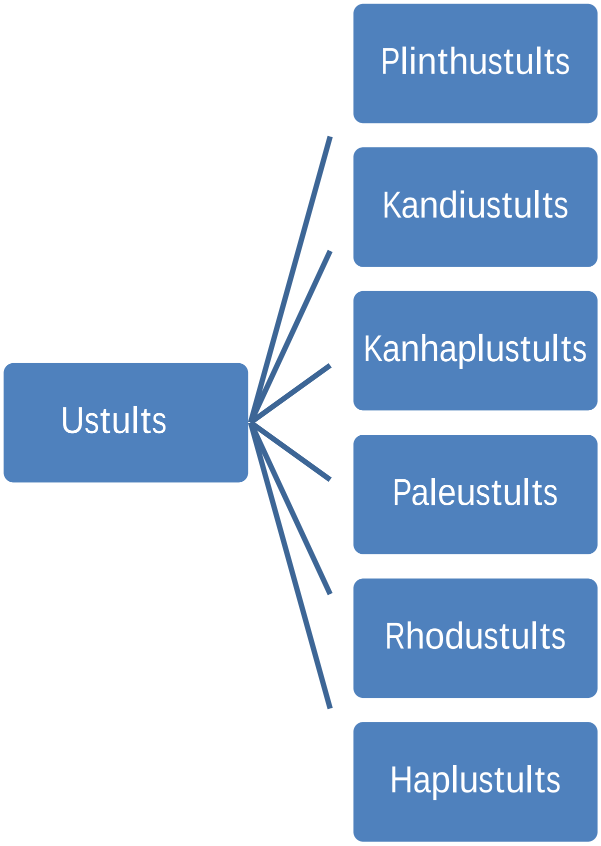
Return to Hapludults

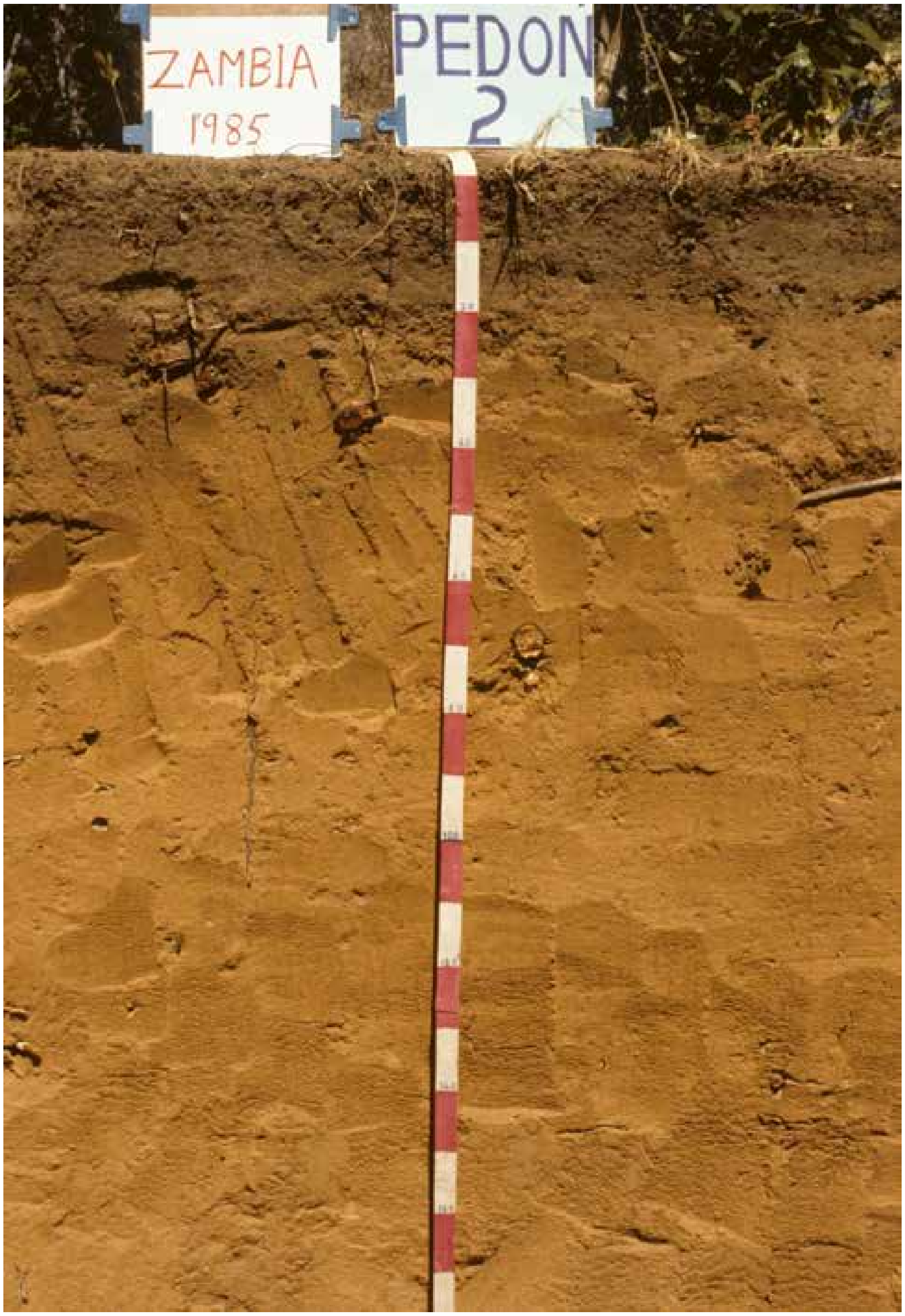
Ustults Great Groups

Ustults are the more or less freely drained Ultisols of subhumid to semiarid regions where amounts of rainfall are moderately low to high but evapotranspiration exceeds precipitation most of the year. Some Ustults have a single dry season each year, such as those in a monsoon climate, and others have alternating moist and dry periods throughout the growing season. Ustults have an ustic soil moisture regime and a relatively low content of organic carbon.

Most Ustults have an ochric (typically thin and/or light-colored) epipedon that overlies an argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon, which may or may not contain plinthite (firm, iron oxide-rich concentration). A petroferric (cemented by iron with little or no organic matter) contact is common in some parts of the world.

The vegetation commonly consists of forest or savanna plants. Ustults are of small extent in the United States.





Profile of an Ustult (specifically a Kandiustult) in Zambia. This soil has a reddish yellow kandic horizon beginning at a depth of about 20 centimeters. Scale is in decimeters.

Back to Ustults

Key to Great Groups of Ustults (Back to key to suborders)

Ustults that have:

1. **Plinthite making up ≥ 50% of a layer within a depth of 150 cm --- Plinthustults**
   Begin measuring depth below any O horizon. Plinthite is a firm, iron oxide-rich concentration that irreversibly hardens after exposure to repeated wet-dry cycles.

2. **A kandic (very low cation-exchange capacity) horizon and a clay content does not decrease significantly within a depth of 150 cm --- Kandiustults**
   Clay content must not decrease by ≥ 20% of the maximum in the kandic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below. Kandiustults cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

3. **A kandic (very low cation-exchange capacity) horizon and a significant decrease in clay content within a depth of 150 cm --- Kanhaplustults**
   Begin measuring depth below any O horizon.

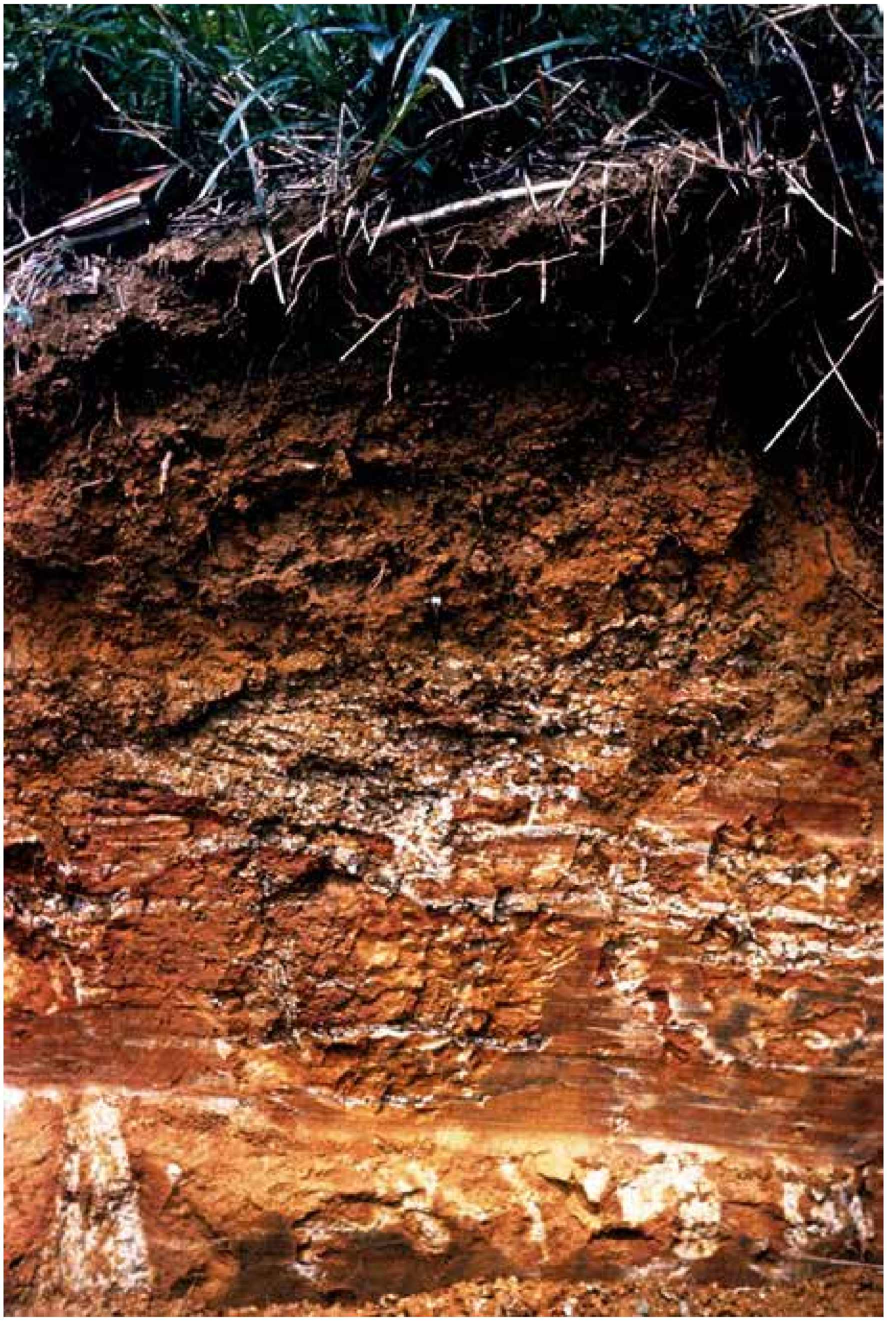
4. **An argillic (clay accumulation) subsoil horizon and a clay content that does not decrease significantly within a depth of 150 cm --- Paleustults**
   Clay content must not decrease by ≥ 20% of the maximum in the argillic horizon, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below. Paleustults cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

5. **Both a dark surface layer and a dark, reddish argillic (clay accumulation) subsoil horizon ------------------------------------ Rhodustults**
   The surface and subsoil have moist value of ≤ 3. The hue of the argillic horizon is mostly 2.5YR or redder and its value increases no more than 1 unit when dry. Argillic color requirement applies to a depth of 100 cm, or to the entire argillic horizon if thinner. Begin measuring depth below any O horizon.

6. **An argillic (clay accumulation) horizon and a significant decrease in clay content within a depth of 150 cm --------------------------- Haplustults**
   Begin measuring depth below any O horizon.

Descriptions of Great Groups of Ustults

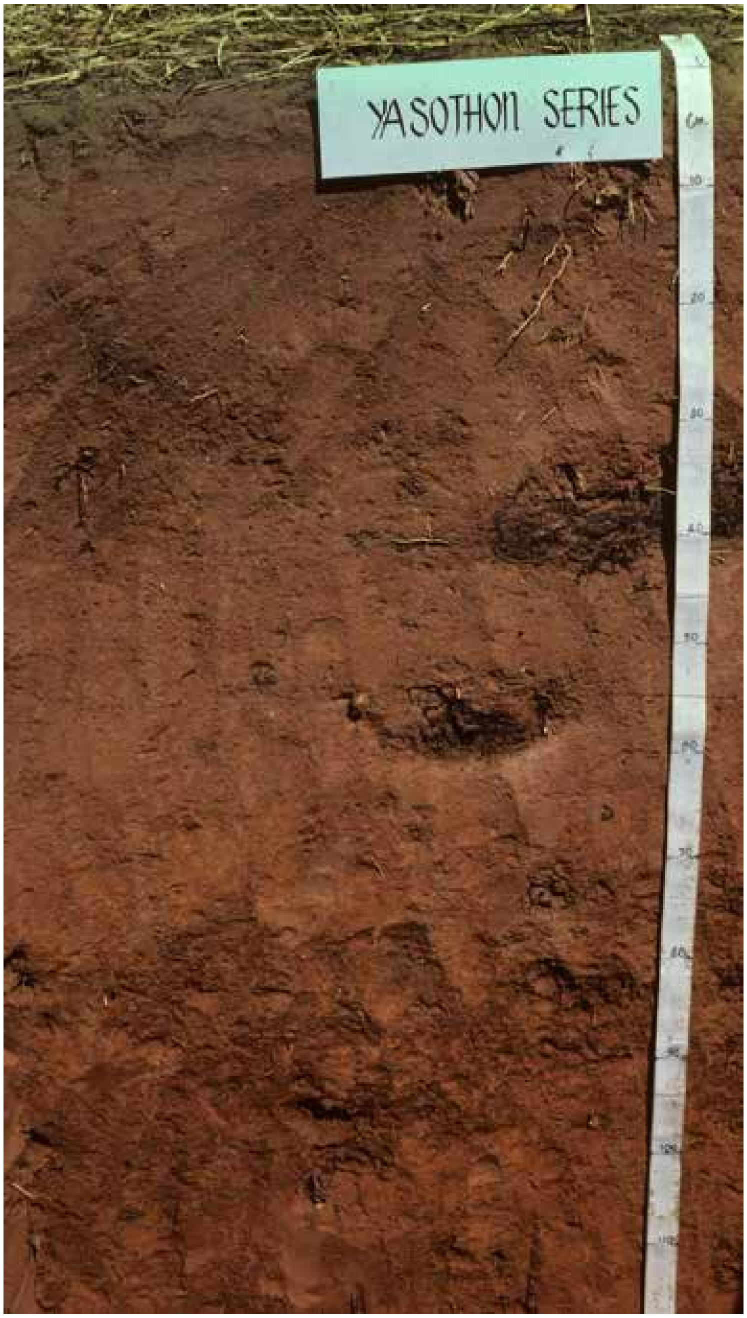
Plinthustults—These soils have a large amount of plinthite (firm, iron oxide-rich concentration) in the subsoil. Slopes are mostly gentle or moderate. These soils are not known to occur in the United States or in Puerto Rico. The great group is provided for use in other parts of the world. (Back to Ustults key)



Profile of a moderately well drained, loamy Plinthustult in Malaysia. This soil has an ochric epipedon about 25 cm thick underlain by a reddish brown argillic horizon. The lower half of the profile is firm and restricts the movement of water. Water tends to periodically perch above this layer and move laterally, resulting in the gray colors in the middle part of the profile. The dark red areas in the lower part of the profile are plinthite. The depth of this profile is about 150 cm.

Return to Plinthustults

Kandiustults—These soils have a kandic (very low cation-exchange capacity) subsoil horizon. They have a clay distribution in which the percentage of clay does not decrease from its maximum amount by as much as 20% within a depth of 150 cm. The natural vegetation consisted of forest. Many of the soils have been cleared and are used as cropland or pasture.
(Back to Ustults key)



Profile of a well drained, highly weathered Kandiustult in Thailand. This soil has a sandy ochric epipedon consisting of a darkened surface layer (about 22 cm thick) and an underlying lighter-colored layer from which clay has been leached (between depths of 22 and 75 cm). The subsoil below 75 cm is a loamy kandic horizon that is slightly darker in color than the sandy layer above. Scale is in 10-cm increments.

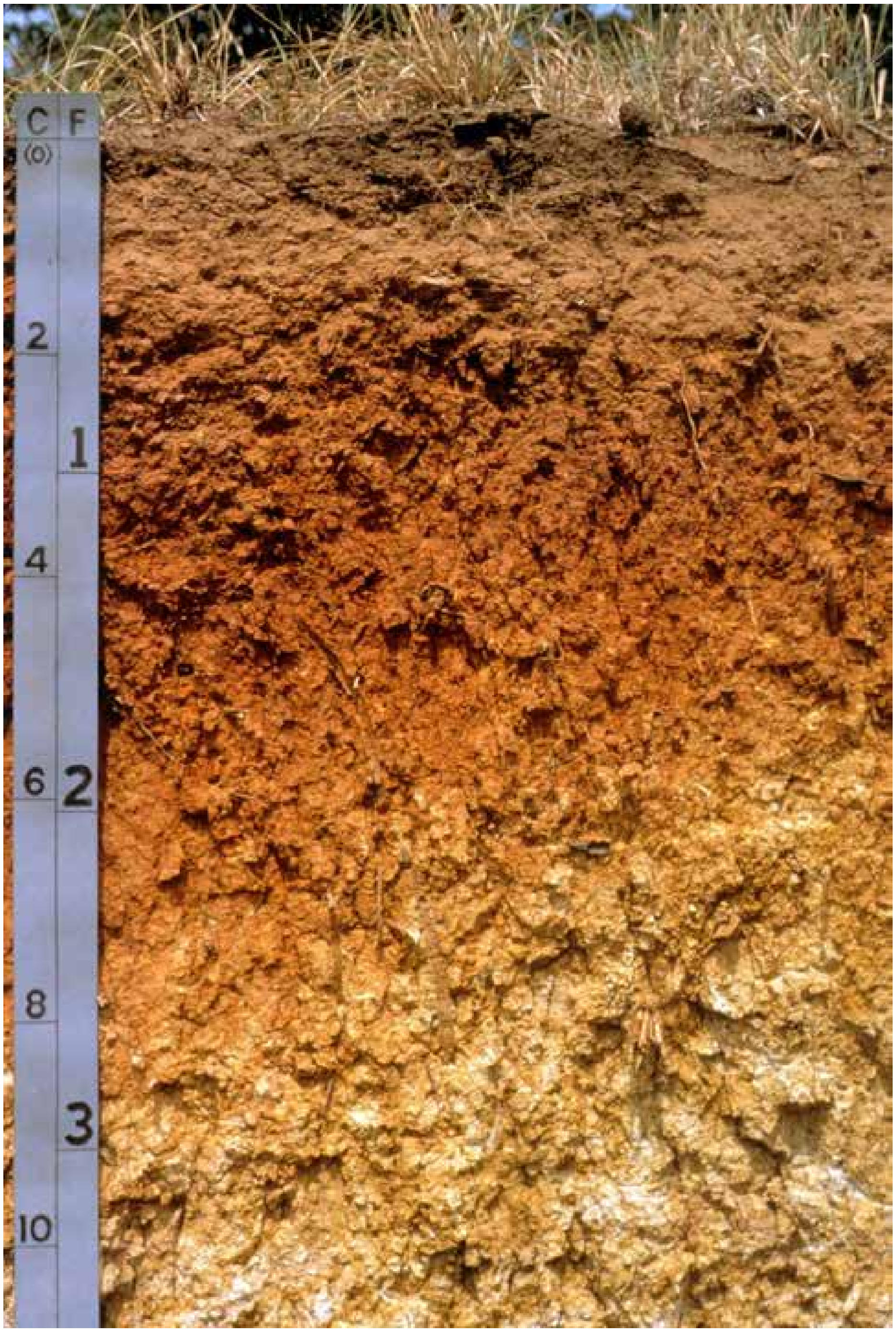
Return to Kandiustults

Kanhaplustults—These soils have a kandic (very low cation-exchange capacity) subsoil horizon. They have a clay distribution in which the percentage of clay decreases significantly within a depth of 150 cm. These soils have a thin to moderately thick zone of maximum clay content. Slopes range from gentle to very steep. Many of the soils are in tropical climates and are farmed by means of shifting cultivation. Kanhaplustults are not known to occur in the United States. They are defined for use in other parts of the world. (Back to Ustults key)

Paleustults—These soils have an argillic (clay accumulation) subsoil horizon. They have a clay distribution in which the percentage of clay does not decrease from its maximum amount by as much as 20% within 150 cm from the mineral soil surface. Many of the soils have a thick argillic horizon. Commonly, there are small or moderate amounts of plinthite (firm, iron oxide-rich concentration) at some depth in the soils. Paleustults are on old stable surfaces that have gentle slopes. They are very rare in the United States and are known to occur only in California. (Back to Ustults key)

Rhodustults—These soils have a dark-colored epipedon and a dark red or dusky red argillic (clay accumulation) subsoil horizon. They are moderately deep or have a clay distribution in which the percentage of clay decreases significantly within a depth of 150 cm. These soils have a thin to moderately thick zone of maximum clay content. They formed mainly in material weathered from basic rocks. They tend to have more total phosphorus than most other Ustults. Rhodustults have gentle to steep slopes. Most of these soils formed in alluvium or on slopes dating from the latter half of the Pleistocene, either Illinoian or Wisconsinan. Rhodustults are rare in the United States and are known to occur only on the Pacific Trust Islands. (Back to Ustults key)

Haplustults—These soils have a thin or moderately thick zone of maximum clay content in the argillic (clay accumulation) subsoil horizon. Slopes range from gentle to very steep. Many of these soils are in tropical climates and are farmed by means of shifting cultivation. Haplustults are of small extent in the United States and occur mainly in Texas, California, and Puerto Rico. They are extensive in some parts of the world. (Back to Ustults key)

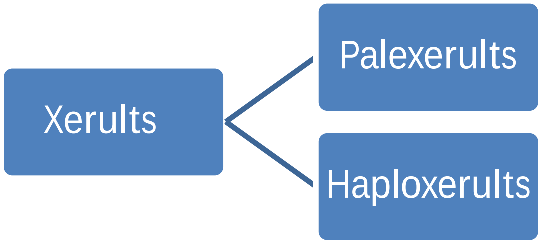


Profile of a moderately well drained, clayey Haplustult in Texas. This soil has an ochric epipedon consisting of a darkened surface layer (about 7 cm thick) and an underlying lighter-colored layer from which clay has been leached (between depths of 7 and 18 cm). Below this epipedon is a yellowish red argillic horizon that becomes reddish yellow to gray in the lower part.

Return to Haplustults

Xerults Great Groups

Xerults are the more or less freely drained Ultisols of Mediterranean-type climates. These soils have a xeric moisture regime (cool and moist in winter and warm and dry in summer) and a moderate or small amount of organic matter. They generally have an ochric (typically thin and/or light-colored) or umbric (humus-rich with low base saturation) epipedon that rests on a brownish to reddish argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon. They are not extensive in the United States, except in California and Oregon, mostly in the mountains. They are gently sloping to very steep. The natural vegetation consisted mostly of coniferous forest plants.



Key to Great Groups of Xerults (Back to key to suborders)

Xerults that have:

1. **An argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon and a clay content that does not decrease significantly within a depth of 150 cm ---------------------------- Palexerults**
Clay content must not decrease by ≥ 20% of the maximum in the subsoil, unless skeletans (ped surfaces stripped of clay) are present in the layer and the clay content increases again by ≥ 3% below. Palexerults cannot have a root-limiting layer within a depth of 150 cm. Begin measuring depth below any O horizon.

2. **An argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon and a significant decrease in clay content within a depth of 150 cm -- Haploxerults**
Begin measuring depth below any O horizon.

Descriptions of Great Groups of Xerults

Palexerults—These soils have a clay distribution in which the percentage of clay does not decrease from its maximum amount by as much as 20% within a depth of 150 cm, or the layer in which the clay percentage decreases has at least 5% of the volume consisting of skeletans (ped surfaces stripped of clay) and there is at least a 3% increase in clay content below this layer. These soils are mainly on older surfaces in the Cascades and coastal mountains of Oregon and California. Slopes are gentle to very steep. Palexerults are probably rare in the world, but they may be extensive locally in areas of humid Mediterranean-type climates. (Back to Xerults key)

Haploxerults—These soils have a clay distribution in which the percentage of clay decreases significantly within a depth of 150 cm. These soils have a thin or moderately thick zone of maximum clay content. Typically, they have an ochric (typically thin and/or light-colored) epipedon that rests on a brownish or reddish argillic (clay accumulation) or kandic (very low cation-exchange capacity) subsoil horizon. In the United States, they occur mostly in the Sierra Nevada and Cascade Mountains and support coniferous forest plants. Haploxerults are moderately extensive in those mountains but are rare elsewhere in the United States. (Back to Xerults key)

Vertisols Order

Vertisols are very clayey soils that shrink and crack when dry and expand when wet.

General Characteristics

Vertisols are very clayey soils that have deep, wide cracks during dry seasons. All Vertisols are dominated by clay minerals (smectites) that dramatically shrink when dry and swell when moistened. These soils tend to be very sticky and plastic when wet and very firm and hard when dry. They are commonly very dark in color due to the deep mixing resulting from the shrink-swell cycles which churn the soil. Vertisols commonly have slickensides (shiny, striated structural surfaces) that are produced by the shrink-swell process. As a result of the churning, distinct soil horizons are often difficult to discern. Many Vertisols have a mollic (rich in humus and bases) epipedon and a cambic (minimal soil development) subsoil horizon. A few have an argillic (clay accumulation), natric (high levels of illuvial clay and sodium), or calcic (calcium carbonate accumulation) subsoil horizon.

Environment and Processes

Vertisols generally have gentle slopes, but a few are strongly sloping. The natural vegetation is predominantly grass or savanna, but a few are in forest or desert shrub. Vertisols are known to occur in a wide range of climatic environments, but all Vertisols require a climate (whether cool or hot) in which seasonal drying occurs. The ideal climate seems to be that with a wet-dry monsoonal pattern that accentuates the shrink-swell cycles.

Vertisols form over a variety of parent materials, most of which are neutral or calcareous. The materials include calcareous sandstone, shale, chalk, limestone, ash deposits, base-rich igneous rocks, and clayey alluvium derived from these or similar sources. Conditions that allow relatively low leaching are important so that the clays do not weather to mineral species with less potential for shrinking and swelling.

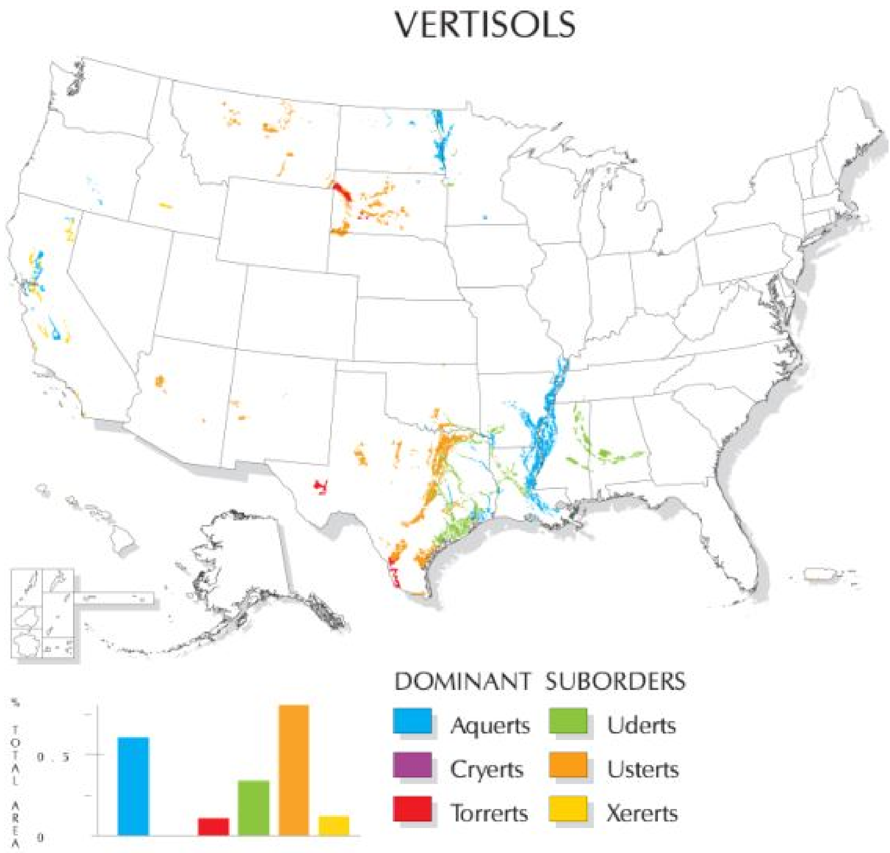
Some Vertisols, mostly those in more humid areas, developed a unique pattern of microrelief known as gilgai. Gilgai is an intricate pattern of micro-highs and -lows that repeat over scales of about 3 to 10 meters. These areas have complex patterns of hydrology and vegetation.

Location

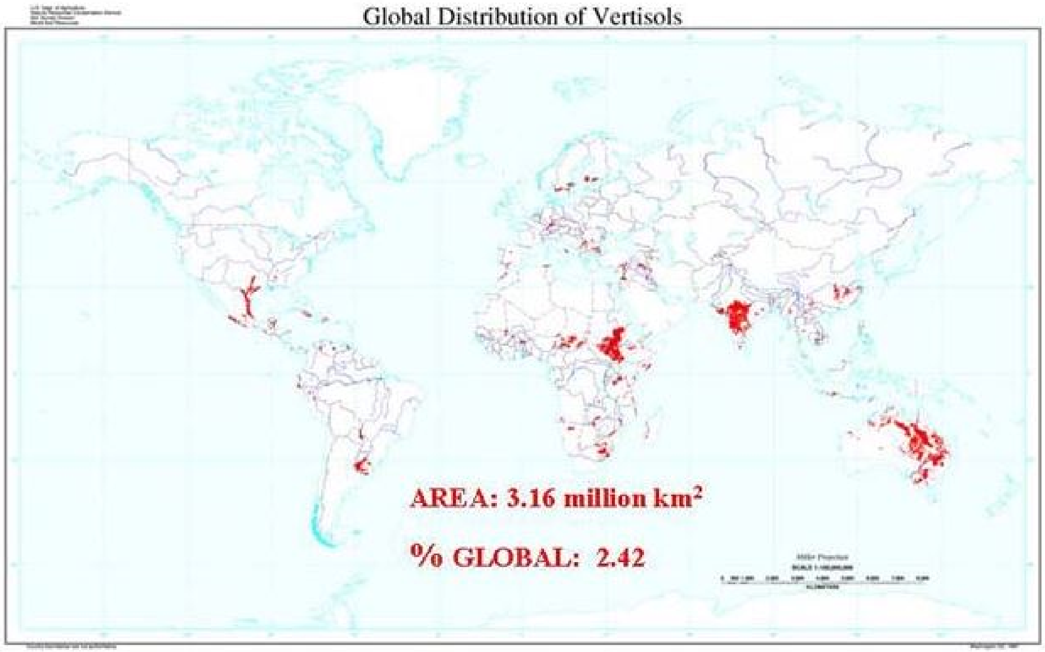
Globally, Vertisols occupy about 2% of the ice-free land area. These soils occur mostly between latitudes of about 50 degrees north and 45 degrees south. They are common in parts of Sudan, Ethiopia, China, India, Bangladesh, Australia, and Uruguay. In the United States, Vertisols are common in the southern parts of the Great Plains and Mississippi River Valley and in the Alabama and Mississippi Blackland Prairie, the Red River Valley, western South Dakota, central California, and a few areas in the Pacific Northwest.

Profile of a Vertisol.

(Back to Key to Soil Orders)



Vertisols by suborder in the United States.



Global distribution of Vertisols.

Vertisols Suborders

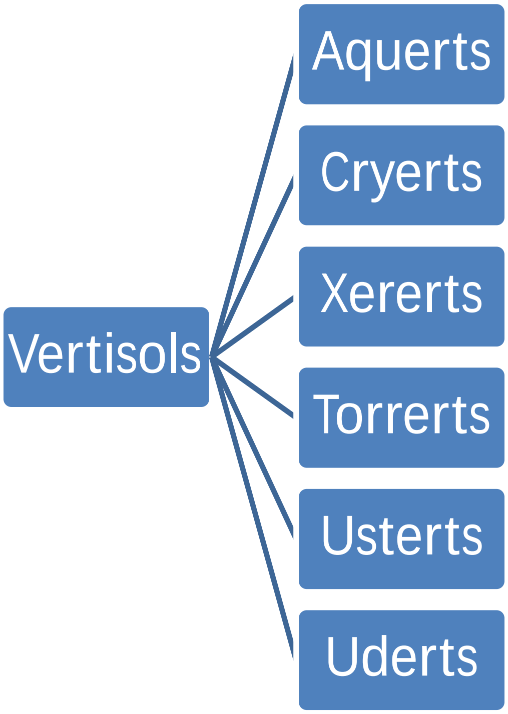
Classification of Vertisols

In the definitions of the suborders, emphasis is given to soil climate. Five suborders are based on moisture regime (Aquerts, Xererts, Usterts, Torrerts, and Uderts) and one is based on temperature regime (Cryerts). The defined moisture regimes, however, have little significance because water from rainfall commonly runs into cracks so that the soils are remoistened from both above and below. Because of the difficulty in defining soil moisture regimes in Vertisols, the duration that cracks are open or closed is used to differentiate the suborders.

The great group level reflects a combination of important properties, including the presence of various diagnostic horizons, the presence of cemented layers, electrical conductivity and pH, significant carbon accumulation in the upper part of the soil, and patterns of soil saturation.

The six suborders are:

1. Aquerts—wet Vertisols (aquic conditions in the upper part)
2. Cryerts—cold Vertisols (cryic temperature regime)
3. Xererts—Vertisols with seasonal cracking pattern indicative of a xeric moisture regime (cool and moist in winter and warm and dry in summer)
4. Torrerts—Vertisols with seasonal cracking pattern indicative of a torric (arid) moisture regime
5. Usterts—Vertisols with seasonal cracking pattern indicative of an ustic moisture regime (moisture is limited, but available, during portions of the growing season)
6. Uderts—Vertisols with seasonal cracking pattern indicative of a udic moisture regime (seasonally well-distributed rainfall)


Vertisols
Aquerts
Cryerts
Xererts
Torrerts
Usterts
Uderts

Key to Suborders of Vertisols

Vertisols that have:

1. **A seasonal high water table within a depth of 50 cm ------------- Aquerts**
   Evidence of a water table includes redoximorphic features (gray and red color patterns). See 12th edition of "Keys to Soil Taxonomy" for criteria regarding amount, color, and location of redoximorphic features. Begin measuring depth below any O horizon. Artificially drained sites are included in Aquerts.

2. **Cold average soil temperature --- Cryerts**
   These soils have a cryic soil temperature regime.

3. **Cracks in the upper 50 cm that are open ≥ 90 consecutive days in summer and closed ≥ 90 consecutive days in winter ------------- Xererts**
   Seasonal cracking pattern pertains to nonirrigated soils. Cracks are ≥ 5 mm wide and extend through ≥ 25 cm of the upper 50 cm. Xererts have a frigid, mesic, or thermic soil temperature regime.

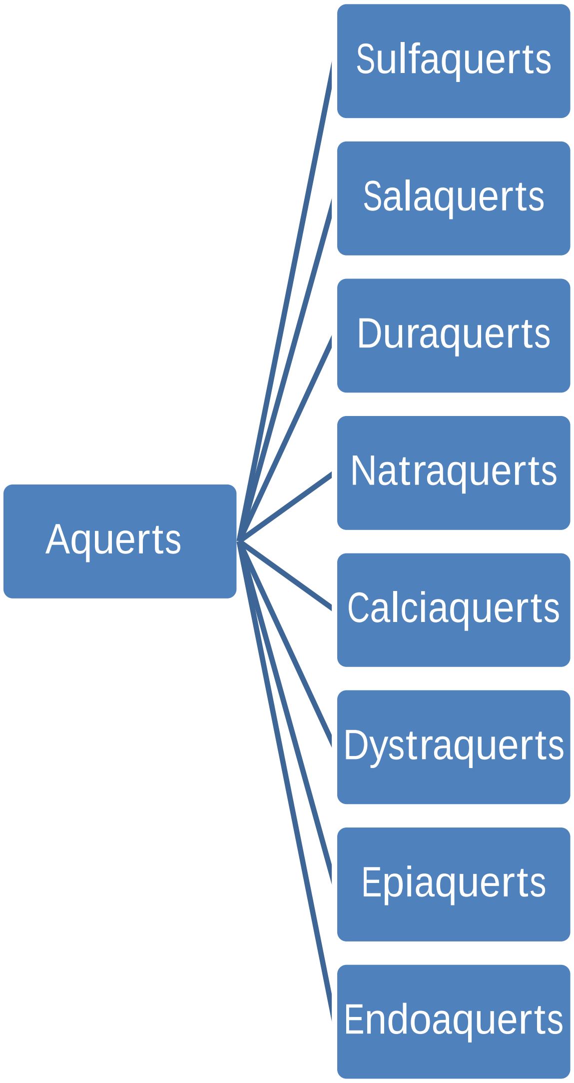
4. **Cracks in the upper 50 cm that are closed < 60 consecutive days when the soil temperature is > 8 °C ----------------------------------- Torrerts**
   Seasonal cracking pattern pertains to nonirrigated soils. Soil temperature is recorded at a depth of 50 cm. The temperature of 8 °C is used to approximate the growing season.

5. **Cracks in the upper 50 cm that are open ≥ 90 cumulative days each year --- Usterts**
   Seasonal cracking pattern pertains to nonirrigated soils. Cracks are ≥ 5 mm wide and extend through ≥ 25 cm of the upper 50 cm.

6. **Cracks in the upper 50 cm that are open < 90 cumulative days each year --- Uderts**
   Seasonal cracking pattern pertains to nonirrigated soils. Cracks are ≥ 5 mm wide and extend through ≥ 25 cm of the upper 50 cm.

Aquerts Great Groups

Aquerts are the wet Vertisols. They are saturated to the surface by ground water for a long enough period during the year to become devoid of oxygen (aquic conditions). However, they also are dry for periods long enough during the year for cracks to open. These soils are typically in low areas, such as glacial lake plains, flood plains, stream terraces, and depressions.



Profile of an Aquert (specifically an Endoaquert) in Thailand. Redoximorphic features are throughout the profile. A lithologic discontinuity to underlying loamy material is at a depth of about 110 cm. Scale is in cm.

Return to Aquerts

Key to Great Groups of Aquerts (Back to key to suborders)

Aquerts that have:

1. **A sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon OR sulfidic materials (acid-producing, oxidizable sulfur compounds) within a depth of 100 cm -------------------------- Sulfaquerts**
   Begin measuring depth below any O horizon.

2. **A salic (high content of salts) horizon within a depth of 100 cm -- Salaquerts**
   Begin measuring depth below any O horizon.

3. **A duripan (layer cemented by silica) within a depth of 100 cm --- Duraquerts**
   Begin measuring depth below any O horizon.

4. **A natric (high levels of illuvial clay and sodium) horizon within a depth of 100 cm -- Natraquerts**
   Begin measuring depth below any O horizon.

5. **A calcic (calcium carbonate accumulation) horizon within a depth of 100 cm -- Calciaquerts**
   Begin measuring depth below any O horizon.

6. **Very strongly acid pH (and low salinity) in the upper 50 cm -- Dystraquerts**
   The pH is $\leq$ 4.5 in 0.01 M $CaCl_2$ (5.0 or less in 1:1 water). Electrical conductivity in the saturation extract is $\leq$ 4.0 dS/m. The pH and salinity criteria must be met in at least 25 cm of the upper 50 cm.

7. **Episaturation (perched water table) ------------------------------- Epiaquerts**

8. **Endosaturation (saturated throughout the profile) --------- Endoaquerts**

Descriptions of Great Groups of Aquerts

Sulfaquerts—These soils have an appreciable amount of sulfides close to the soil surface as either sulfidic materials (acid-producing, oxidizable sulfur compounds) or a sulfuric (highly acid due to oxidation and production of sulfuric acid) horizon. The sulfides are close enough to the surface for the soils to become extremely acid and virtually barren if drained. These soils are not known to occur in the United States. They have been recognized in coastal areas, including river deltas in South Asia. (Back to Aquerts key)

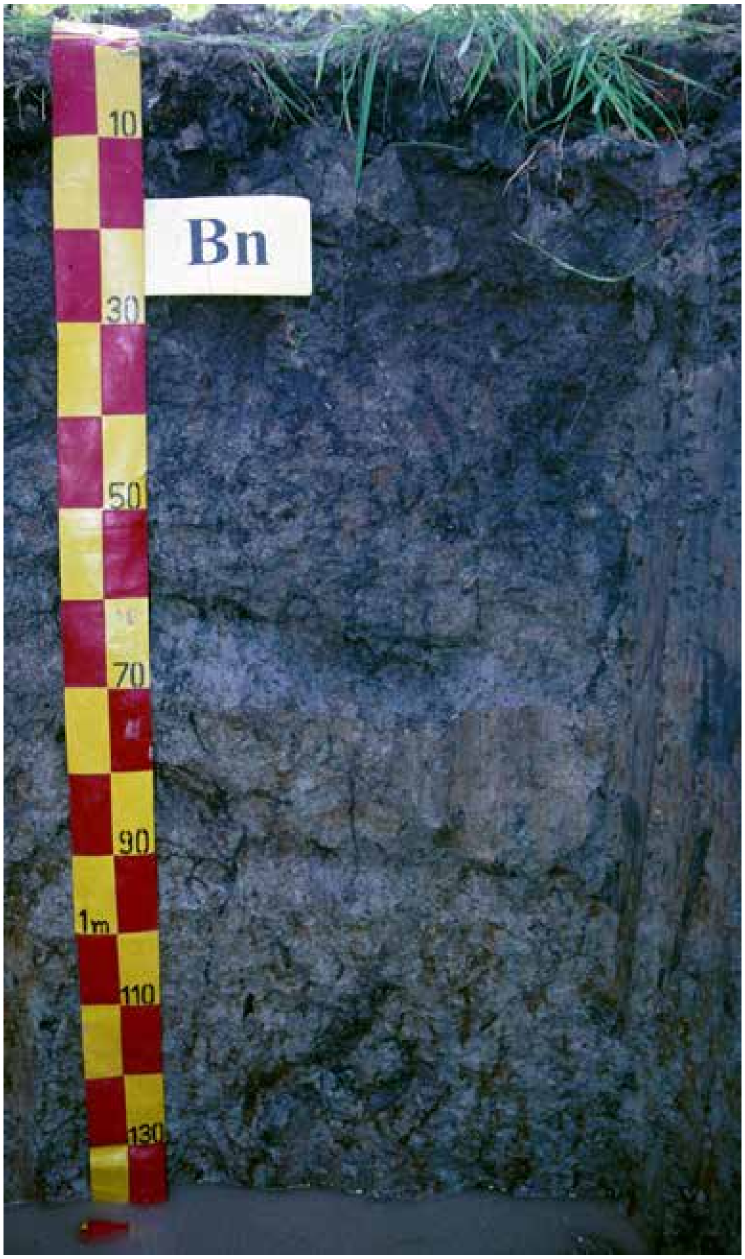
Salaquerts—These soils have a salic (high content of salts) horizon. They are not known to occur in the United States. (Back to Aquerts key)

Duraquerts—These soils have a duripan (layer cemented by silica). They commonly are derived from volcanic materials. In the United States, all of these soils have aquic conditions (saturated and depleted of oxygen) for part of the year and either have a xeric moisture regime (cool and moist in winter and warm and dry in summer) or border a xeric moisture regime. (Back to Aquerts key)

Natraquerts—These soils have a natric (high levels of illuvial clay and sodium) subsoil horizon. In many areas, they occur on flood plains or glacial lake plains. The high sodium content limits their use as cropland. Most of the soils are used as rangeland, pasture, or hayland. Most Natraquerts in the United States formed in alluvium or lacustrine deposits derived dominantly from sedimentary rocks. Natraquerts occur in North Dakota, South Dakota, Montana, Iowa, Nebraska, and Texas. (Back to Aquerts key)

Calciaquerts—These soils have a calcic (calcium carbonate accumulation) subsoil horizon. In addition, they commonly have a mollic (rich in humus and bases) epipedon. In the United States, these soils occur on the northern Great Plains. They are used mostly for crops. (Back to Aquerts key)

Dystraquerts—These soils have dominantly low pH values and low electrical conductivity in the upper 50 cm. They commonly occur in low areas, such as flood plains and terraces, but a few occur on uplands. These soils are found in portions of the southern United States. Many of them are cropped or are in pasture, but some are forested. (Back to Aquerts key)

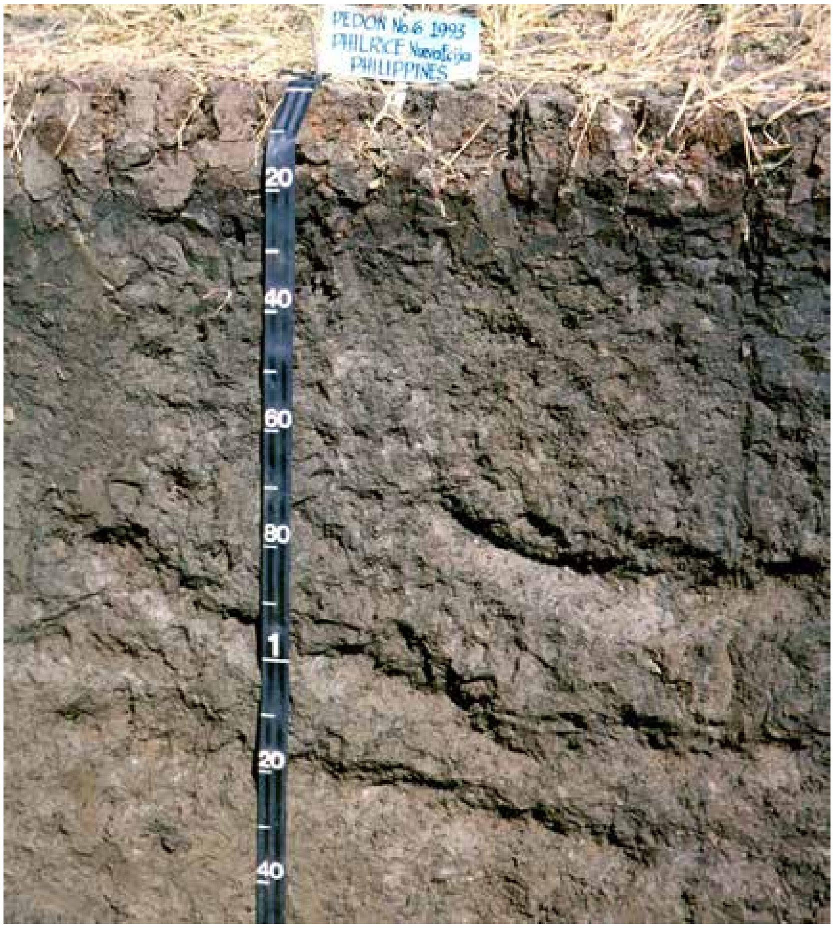


Profile of a poorly drained Dystraquert in Thailand. This clayey soil has an ochric epipedon about 20 cm thick underlain by a cambic horizon. There are reddish brown and gray redoximorphic features throughout the profile. Note the water table below a depth of 130 cm. Scale is in 10-cm increments.

Return to Dystraquerts

Epiaquerts—These soils have one or more soil layers that perch water. These layers are commonly close to the surface. Epiaquerts occur on a variety of landforms, including flood plains, glacial lake plains, and depressions. In the United States, they occur in several western States, on the northern Great Plains, and in the South. They also occur in Puerto Rico.

(Back to Aquerts key)



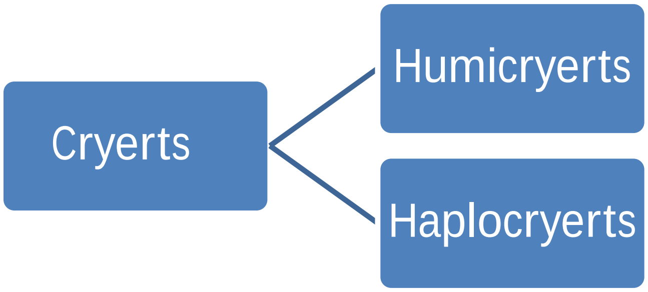
Profile of an Epiaquert in the Philippines. This soil is used for rice production. It is seasonally saturated in about the upper 120 cm of the profile. Below this depth the soil has brighter colors and lacks redoximorphic depletions. This indicates that water perches above this depth. The three slightly curved horizontal features at depths of about 80, 100, and 120 cm are large slickensides exposed for the soil description. Scale is in cm.

Return to Epiaquerts

Endoaquerts—These soils are saturated throughout the profile. They occur in the far western States, on the northern Great Plains, and in the southern States. (Back to Aquerts key)

Cryerts Great Groups

Cryerts are the Vertisols of cold regions. They have a cryic soil temperature regime. Because these soils are fine textured and in cold temperature regimes, they periodically shrink and swell, the process which forms the diagnostic characteristics of Vertisols. Cracks commonly open once a year, late in the summer. Cryerts occur on the cold prairies of Canada, where they commonly are derived from lacustrine deposits. They also occur in the Rocky Mountains of the United States.



Key to Great Groups of Cryerts (Back to key to suborders)

Cryerts that have:

1. **High amounts of organic carbon in the soil ------------------- Humicryerts**
   These soils have ≥ 10 kg/m^2 organic carbon in the upper 50 cm of the profile. Begin measuring depth below any O horizon.

2. **Moderate to low amounts of organic carbon ----------------- Haplocryerts**
   These soils have < 10 kg/m^2 organic carbon in the upper 50 cm of the profile. Begin measuring depth below any O horizon.

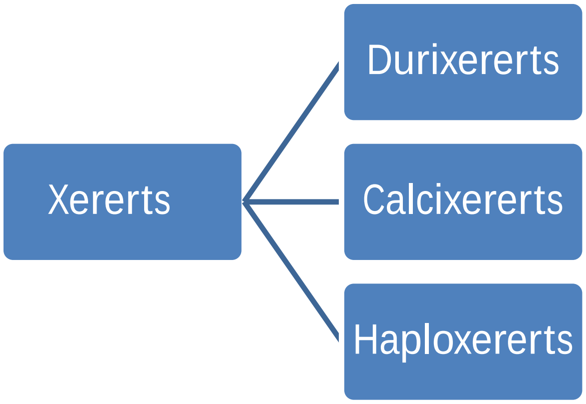
Descriptions of Great Groups of Cryerts

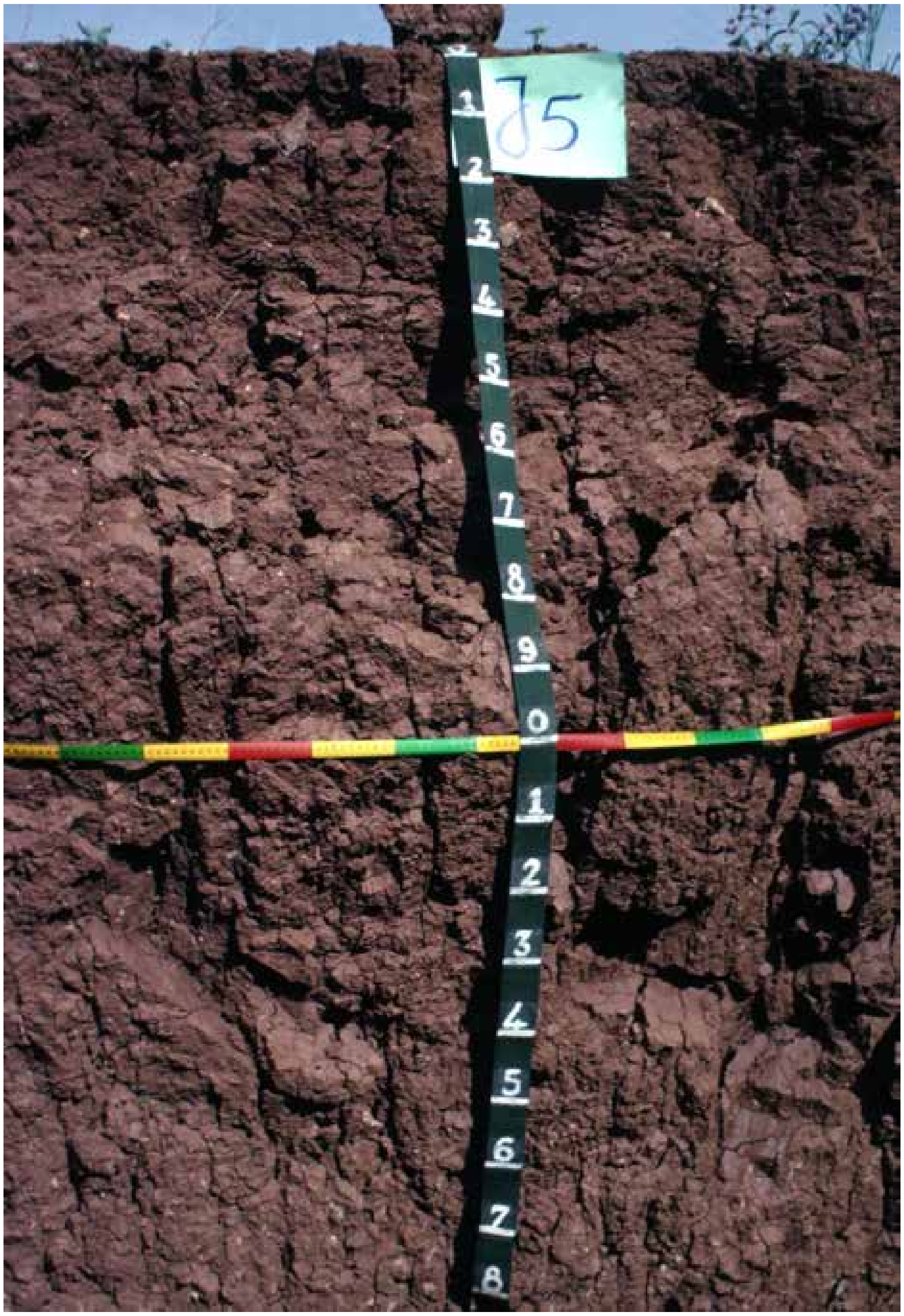
Humicryerts—These soils have relatively high amounts of organic carbon in the upper part of the profile. They formed under a variety of vegetative types. They occur in the Rocky Mountains of the United States. (Back to Cryerts key)

Haplocryerts—These soils have low to moderate accumulations of organic carbon. They occur in the Rocky Mountains of the United States. They are of limited extent. (Back to Cryerts key)

Xererts Great Groups

Xererts are the Vertisols of Mediterranean-type climates, which are typified by cool, wet winters and warm, dry summers. These soils have cracks that regularly close and open each year. Because the soils become dry every summer and are remoistened in winter, damage to structures and roads from shrink-swell processes is very significant. If not irrigated, these soils are used for small grain or grazing. In the United States, most Xererts supported grasses before they were cultivated.





Profile of a Xerert (specifically a Haploxerert) in Jordan. Scale is in decimeters.

Back to Xererts

Key to Great Groups of Xererts (Back to key to suborders)

Xererts that have:

1. **A duripan (layer cemented by silica) within a depth of 100 cm --- Durixererts**
   Begin measuring depth below any O horizon.
2. **A calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon within a depth of 100 cm --- Calcixererts**
   Begin measuring depth below any O horizon.
3. **Little or no calcium carbonate accumulation and no cementation -- Haploxererts**

Descriptions of Great Groups of Xererts

Durixererts—These soils have a duripan (layer cemented by silica). Most are derived from basic igneous rocks, but some formed in mixed alluvium. The Durixererts in the United States occur in California and Idaho and are used for crop production or rangeland. (Back to Xererts key)

Calcixererts—These soils have a calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) subsoil horizon. Many of these soils formed in fine textured sedimentary rocks. In the United States, some Calcixererts are used for irrigated crops. The rest are used as rangeland, pasture, or nonirrigated cropland. (Back to Xererts key)

Haploxererts—These are the most common Xererts. These soils formed in a variety of parent materials, including volcanic and sedimentary rocks, lacustrine deposits, and alluvium. In many areas, they are used for grazing by livestock. In some areas, they are used for citrus, small grain, truck crops, or rice. (Back to Xererts key)

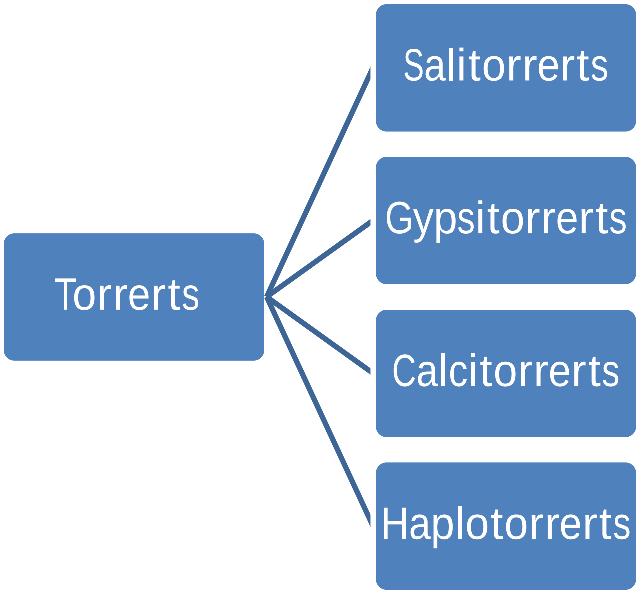
Profile of a Haploxerert in Australia. This soil has an ochric epipedon about 12 cm thick underlain by a cambic horizon. It is clayey in the upper part and loamy below a depth of about 70 cm. Cracks are beginning to form as the soil dries. Scale is in cm.

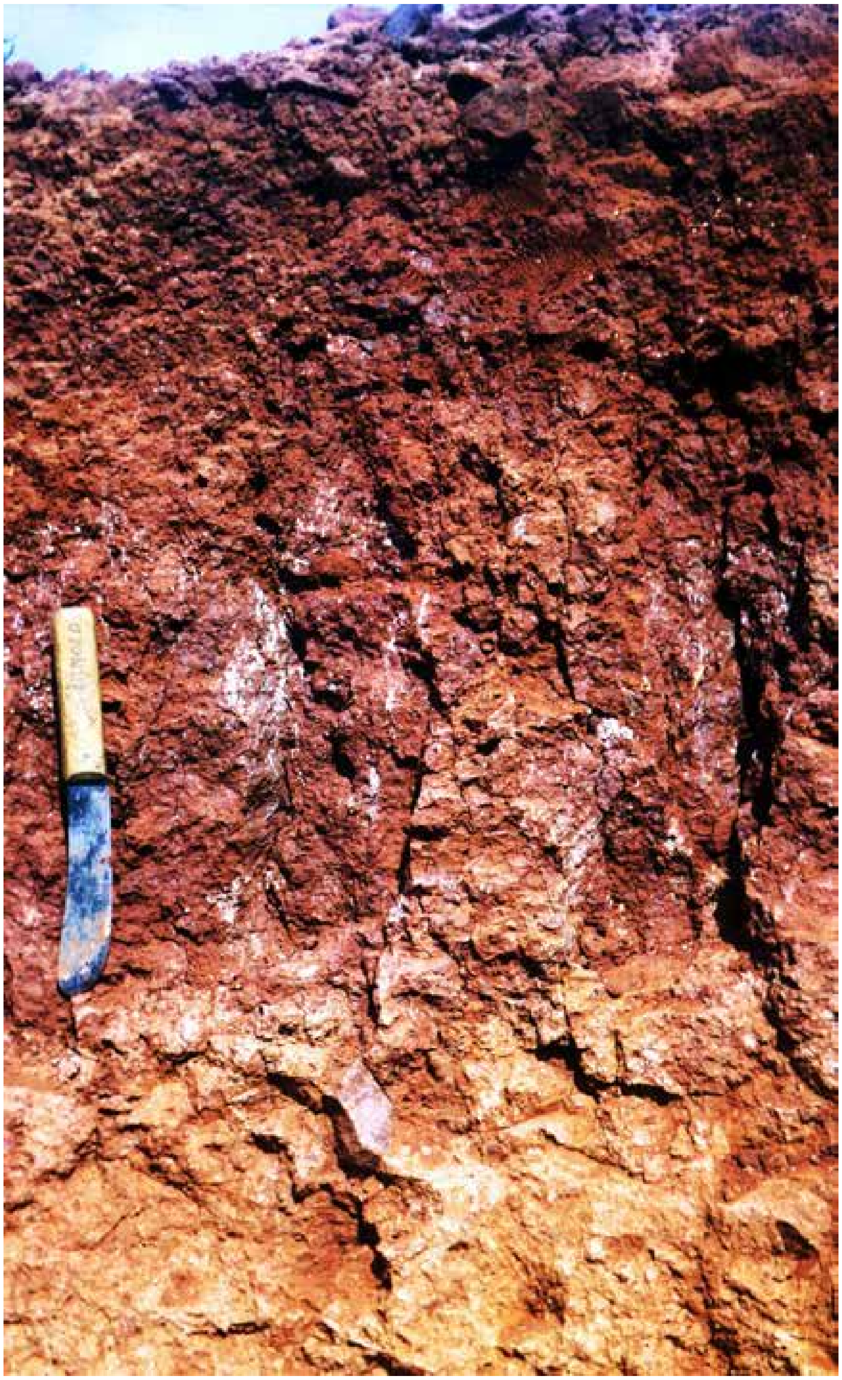
Return to Haploxererts

Torrerts Great Groups

Torrerts are the Vertisols of arid climates. Due to limited amounts of precipitation, these soils have cracks that commonly stay open for most of the year but may close for at least a few days in most years during brief periods of precipitation. The cracks are closed for less than 60 days during the growing season. Many of these soils dot the landscape in closed depressions that may be ponded from time to time by runoff from higher areas. Torrerts that occupy larger, more continuous areas of the landscape are commonly underlain by parent materials, such as basalt, that tend to weather to smectite. As a result of the arid climate, some (but not all) Torrerts have accumulations of salts in the profile.

The Torrerts in the United States occur mostly in the Southwest. A few are in Hawaii. Most commonly, they are used as rangeland.





Profile of a Torrert (specifically a Gypsitorrert) in Sudan. The white streaks in the subsoil (near knife) are accumulations of gypsum.

Back to Torrerts

Key to Great Groups of Torrerts (Back to key to suborders)

Torrerts that have:

1. **A salic (high content of salts) horizon within a depth of 100 cm -- Salitorrerts**
2. **A gypsic (gypsum accumulation) horizon within a depth of 100 cm --- Gypsitorrerts**
3. **A calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon within a depth of 100 cm -- Calcitorrerts**
4. **Little or no accumulation of salts in the profile ------------- Haplotorrerts**

Descriptions of Great Groups of Torrerts

Salitorrerts—These soils have a salic (high content of salts) horizon. In some, salts accumulate because of a periodic water table. In others, scant precipitation and the impermeable nature of the soil facilitate the accumulation of salts. Salitorrerts are rare in the United States. (Back to Torrerts key)

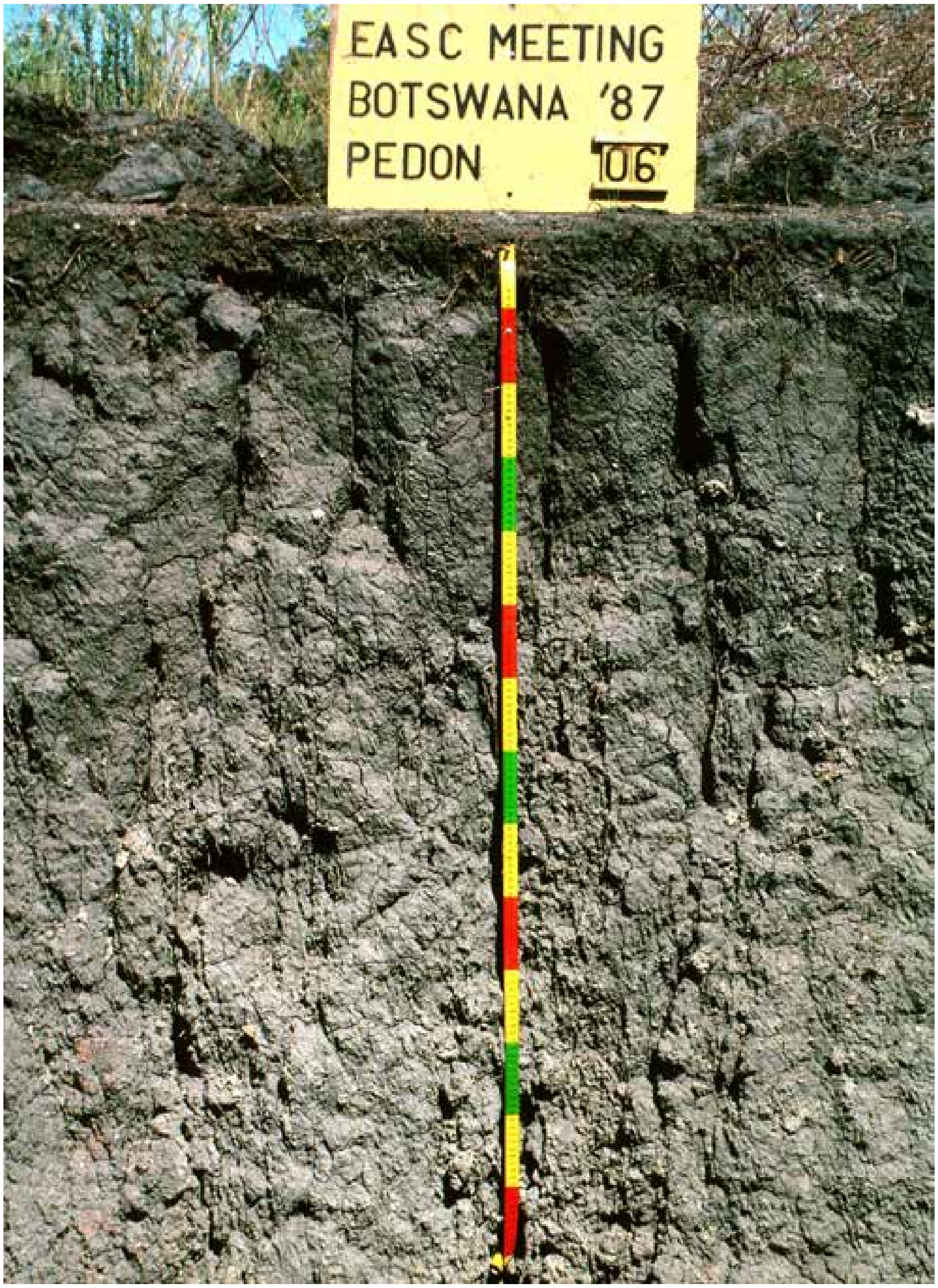
Gypsitorrerts—These soils have a gypsic (gypsum accumulation) subsoil horizon that has its upper boundary within a depth of 100 cm. They occur in arid areas of the world where the parent materials have a high content of gypsum. A high shrink-swell potential and the gypsum content limit many construction activities (urban development) unless measures that counteract the shrinking and swelling and the dissolution of gypsum are applied. These soils occur in the southwestern United States. (Back to Torrerts key)

Profile of a Gypsitorrert in Australia. This soil has an ochric epipedon about 3 inches thick, a cambic horizon between depths of 3 to 15 inches, and a gypsic horizon that extends from a depth of 15 inches to the base of the photo. The whitish material coating the surfaces of the gypsic horizon consists of accumulations of gypsum. Scale is in inches.

Return to Gypsitorrerts

Calcitorrerts—These soils have a calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) subsoil horizon. They are used mostly for grazing by livestock. Some are used for irrigated alfalfa. Calcitorrerts occur in Arizona and other areas of the southwestern United States. (Back to Torrerts key)

Haplotorrerts—These soils have little or no salt accumulation in the profile. This is the most extensive great group of Torrerts. In the United States, these soils occur in many of the western States and in Texas and Hawaii. They are used as urban land, cropland, or rangeland. (Back to Torrerts key)

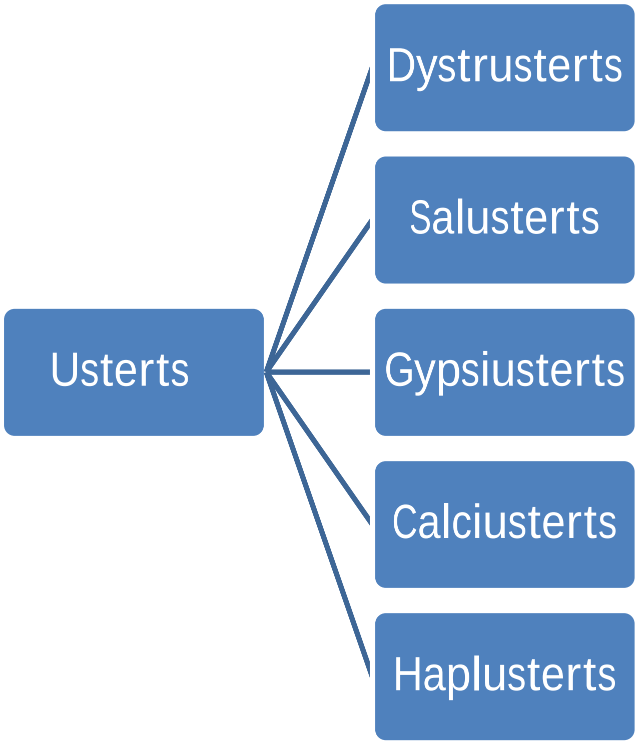


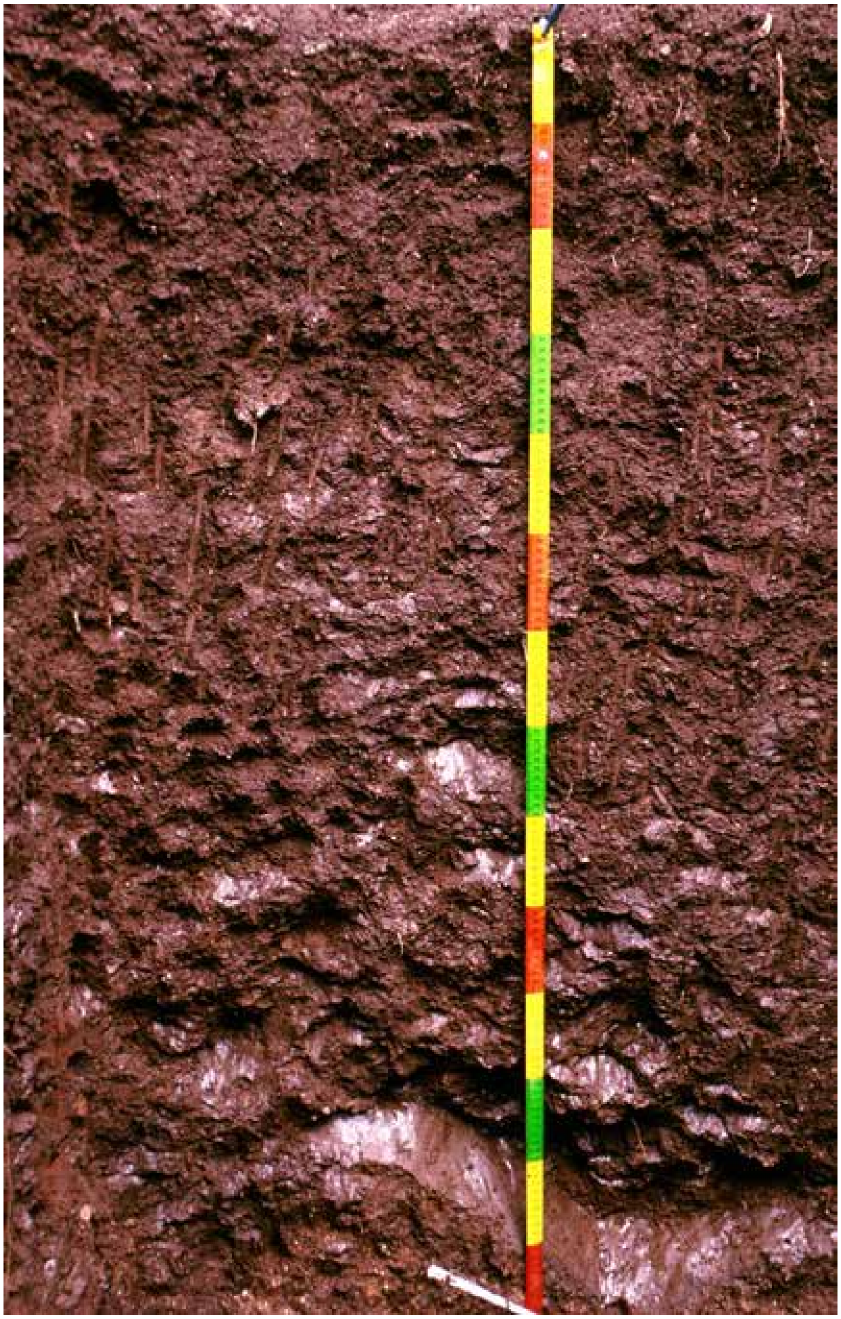
Profile of a Haplotorrert in Botswana. This soil has an ochric epipedon about 10 cm thick. Below this epipedon is a cambic horizon. This particular profile has a significant content of sodium in the upper part of the cambic horizon which has helped to produce columnar structure to a depth of about 65 cm. Scale colors are in 10-cm increments.

Return to Haplotorrerts

Usterts Great Groups

Usterts are the Vertisols in temperate climates that do not receive high amounts of rainfall during the summer, in areas with monsoonal climate, and in tropical and subtropical areas that have two rainy and two dry seasons. Cracks in the soil generally open and close once or twice each year. Usterts are extensive in Texas, on the Great Plains, in Australia, in Africa south of the Sahara, and in India. Many of these soils formed in gently sloping areas of fine textured marine deposits or alluvium. Some are derived from basic igneous rocks. Usterts, if irrigated are intensively cultivated, but large areas are used for grazing because of a lack of the machinery needed for tillage.





Profile of an Ustert (specifically a Hapustert) in India. Slickensides are throughout profile. Note the large slickenside exposed in the lower part of the profile. Scale colors are decimeters.

Back to Usterts

Key to Great Groups of Usterts (Back to key to suborders)

Usterts that have:

1. **Very strongly acid pH (and low salinity) in the upper 50 cm --- Dystrusterts**
   The pH is $\leq$ 4.5 in 0.01 M $CaCl_2$ (5.0 or less in 1:1 water). Electrical conductivity in the saturation extract is $\leq$ 4.0 dS/m. The pH and salinity criteria must be met in at least 25 cm of the upper 50 cm. Begin measuring depth below any O horizon.

2. **A salic (high content of salts) horizon within a depth of 100 cm --- Salusterts**
   Begin measuring depth below any O horizon.

3. **A gypsic (gypsum accumulation) horizon within a depth of 100 cm --- Gypsiusterts**
   Begin measuring depth below any O horizon.

4. **A calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon within a depth of 100 cm --- Calciusterts**
   Begin measuring depth below any O horizon.

5. **Little or no accumulation of salts in the profile -------------- Haplusterts**

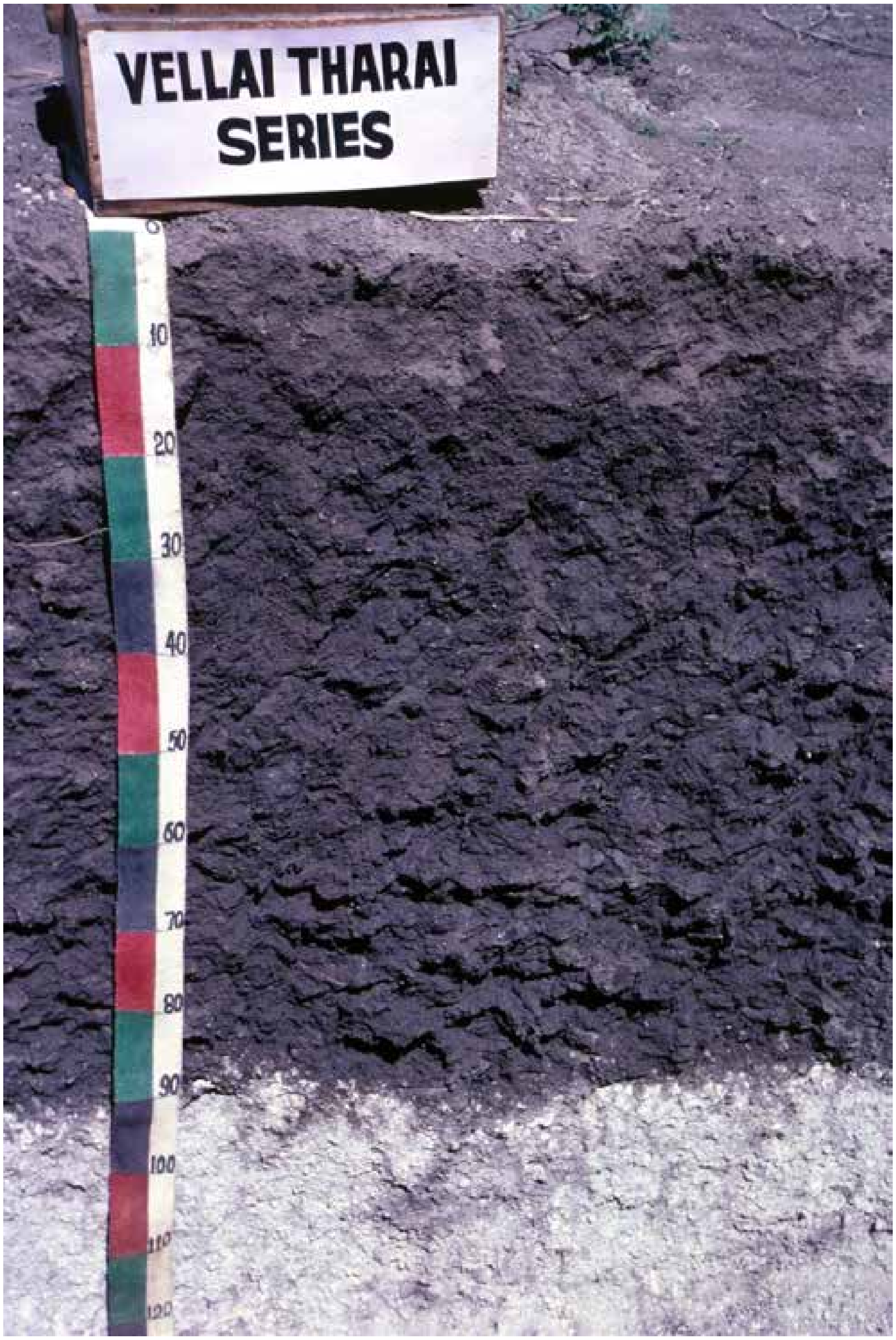
Descriptions of Great Groups of Usterts

Dystrusterts—These soils have a dominant pH value of 5.0 or less (in 1:1 water) and an electrical conductivity of less than 4.0 dS/m within a depth of 50 cm. They commonly form in acid marine clays and are underlain by more alkaline parent materials. They are not known to occur in the United States. (Back to Usterts key)

Salusterts—These soils have a salic (high content of salts) horizon. Many are derived from salty marine deposits. Salts are difficult to leach in Salusterts due to the very slow permeability associated with these soils. As a result, few areas are used as cropland. These soils are not known to occur in the United States. (Back to Usterts key)

Gypsiusterts—These soils have a gypsic (gypsum accumulation) horizon. They are derived from parent materials rich in gypsum. Even in an ustic moisture regime, the gypsum is not leached because of the very slow permeability associated with these soils. Some of the soils occur on the edges of depressions where gypsum accumulates at the capillary fringe. Gypsiusterts are rare in the United States but do occur in Texas, where they are used as rangeland or pasture. (Back to Usterts key)

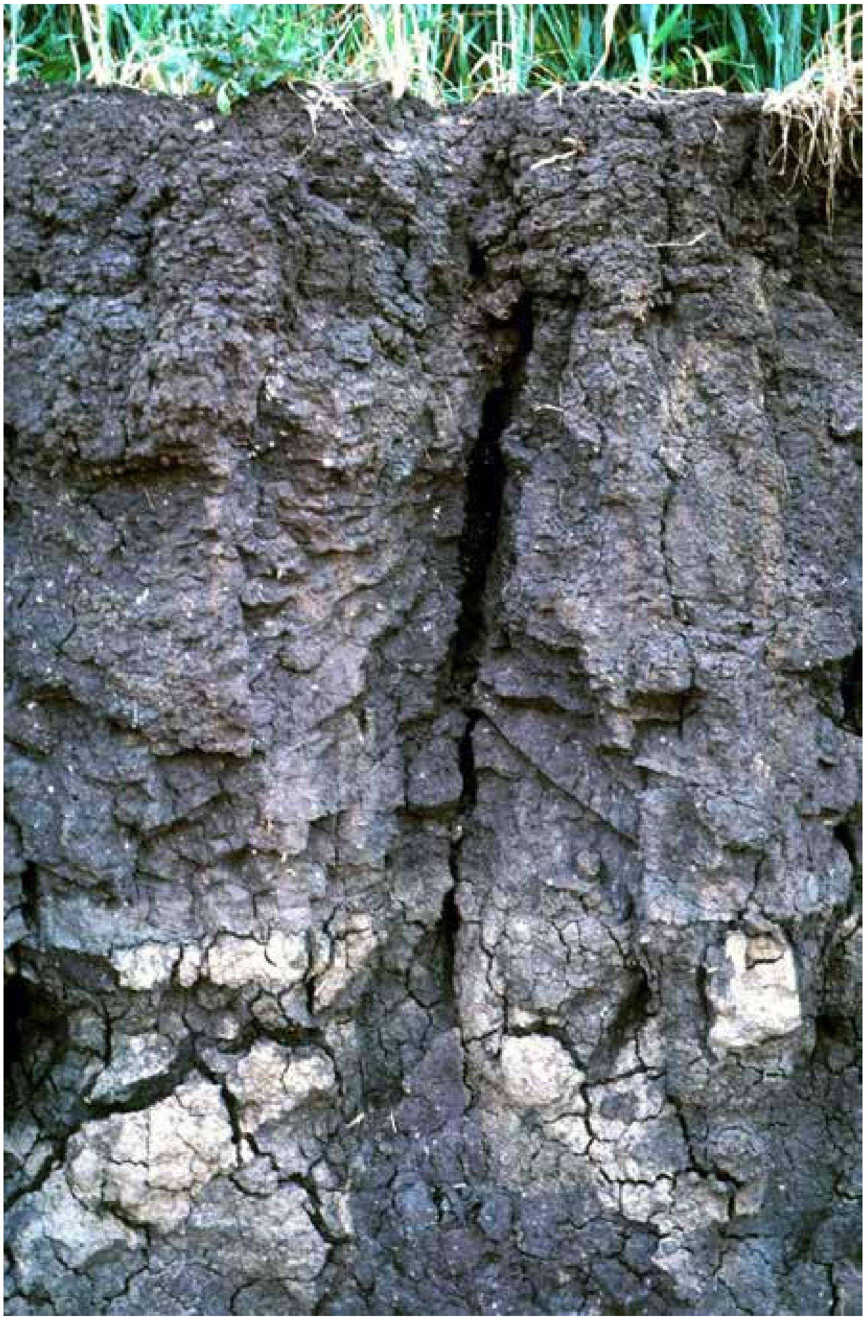
Calciusterts—These soils have a calcic (calcium carbonate accumulation) or petrocalcic (cemented by calcium carbonate) horizon. These soils commonly are derived from parent materials rich in carbonates, such as marine deposits or eolian material. Some Calciusterts have a mollic (rich in humus and bases) epipedon. Although Calciusterts have limited acreage in the United States, they are significant in other parts of the world. (Back to Usterts key)



Profile of a Calciustert in India. This soil has an ochric epipedon about 12 cm thick underlain by a cambic horizon that extends to a depth of about 90 cm. The cambic horizon has slickensides and wedge-shaped peds. A light-colored calcic horizon is below a depth of 90 cm. Scale is in cm.

Return to Calciusterts

Haplusterts—These are the most common Usterts. They have little or no accumulation of salts and a pH value of > 5.0 (in 1:1 water). These soils are derived from a variety of parent materials, including sedimentary rocks, alluvium, marl, and basic igneous rocks. Slopes range from nearly level to strongly sloping. Haplusterts occur in many western and southwestern States, on the northern Great Plains, and in Puerto Rico and the Virgin Islands. They are used as rangeland, cropland, or pasture. (Back to Usterts key)



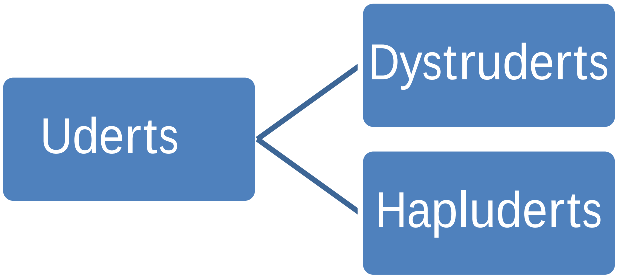
Profile of a well drained, salt-affected Haplustert in a semiarid area of Morocco. This soil has an ochric epipedon about 20 cm thick underlain by a cambic horizon that extends beyond the base of the photo. The cambic horizon has slickensides and wedge-shaped peds. Note the large deep crack. The light gray coatings on peds in the lower third of the profile are accumulations of salt, including sodium. The depth of this soil profile is about 100 cm.

Return to Haplusterts

Uderts Great Groups

Uderts are the Vertisols of humid areas with seasonally well-distributed rainfall. These soils have cracks that open and close, depending upon the amount of precipitation. In some years the cracks may not open completely.

The Uderts in the United States occur on gentle slopes and are derived dominantly from marine shales, chalks, marls, and alluvium. At one time, many of these soils supported native grasses while some supported hardwood or pine forest. Currently, these soils are used for pasture, row crops, or woodland.



Profile of an Udert (specifically a Hapludert) in Texas. Soil churning due to shrinking and swelling has thrust the underlying gray marl upward to the surface (center of photo). The separation of the gray and dark parts of the profile is lined with large slickensides.

Back to Uderts

Key to Great Groups of Uderts (Back to key to suborders)

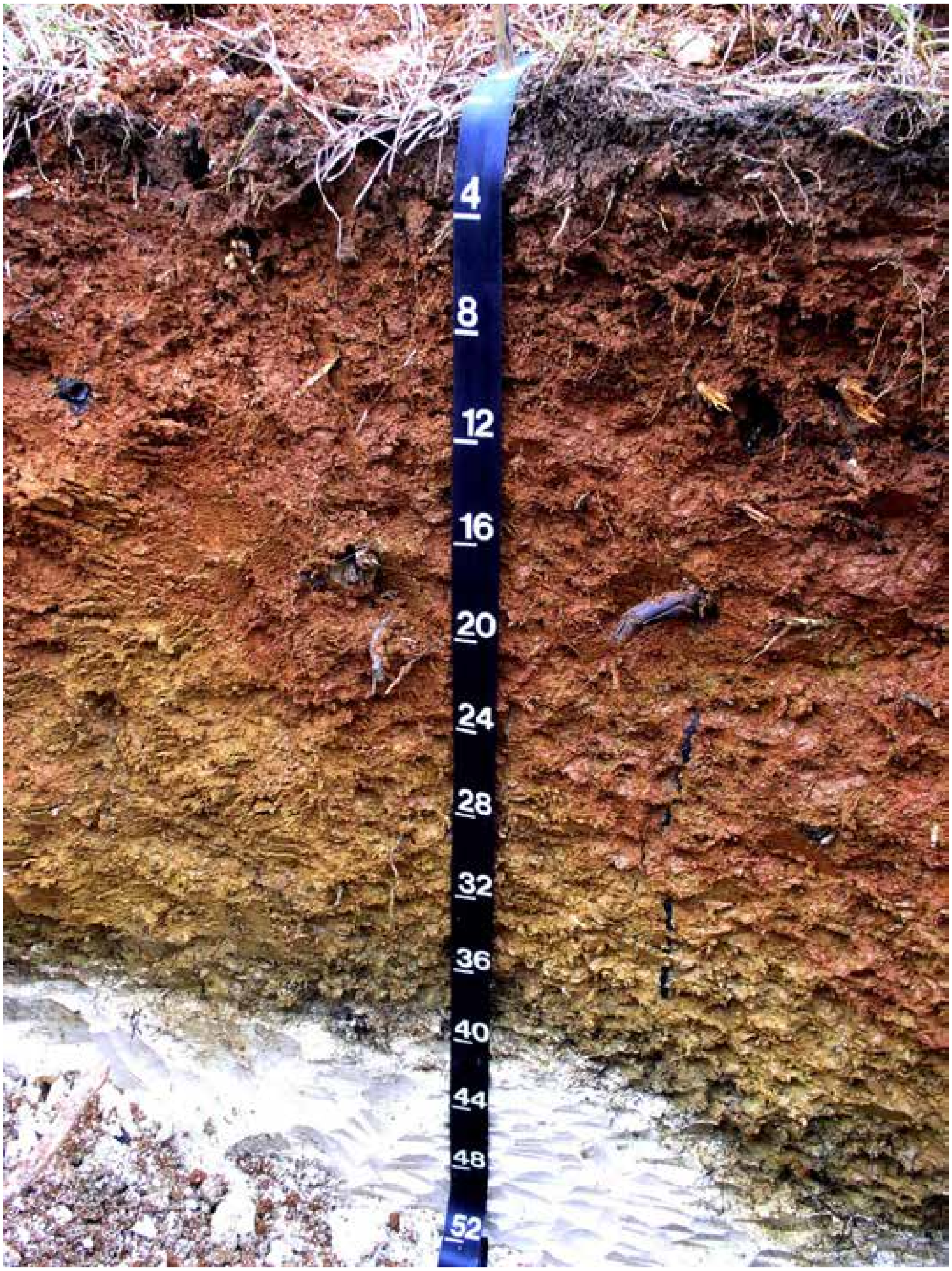
Uderts that have:

1. **Very strongly acid pH (and low salinity) in the upper 50 cm --- Dystruderts**
   The pH is ≤ 4.5 in 0.01 M $CaCl_2$ (5.0 or less in 1:1 water). Electrical conductivity in the saturation extract is ≤ 4.0 dS/m. The pH and salinity criteria must be met in at least 25 cm of the upper 50 cm. Begin measuring depth below any O horizon.

2. **pH > 5.0 (in 1:1 water) in the upper 50 cm ----------------------- Hapluderts**
   Begin measuring depth below any O horizon.

Descriptions of Great Groups of Uderts

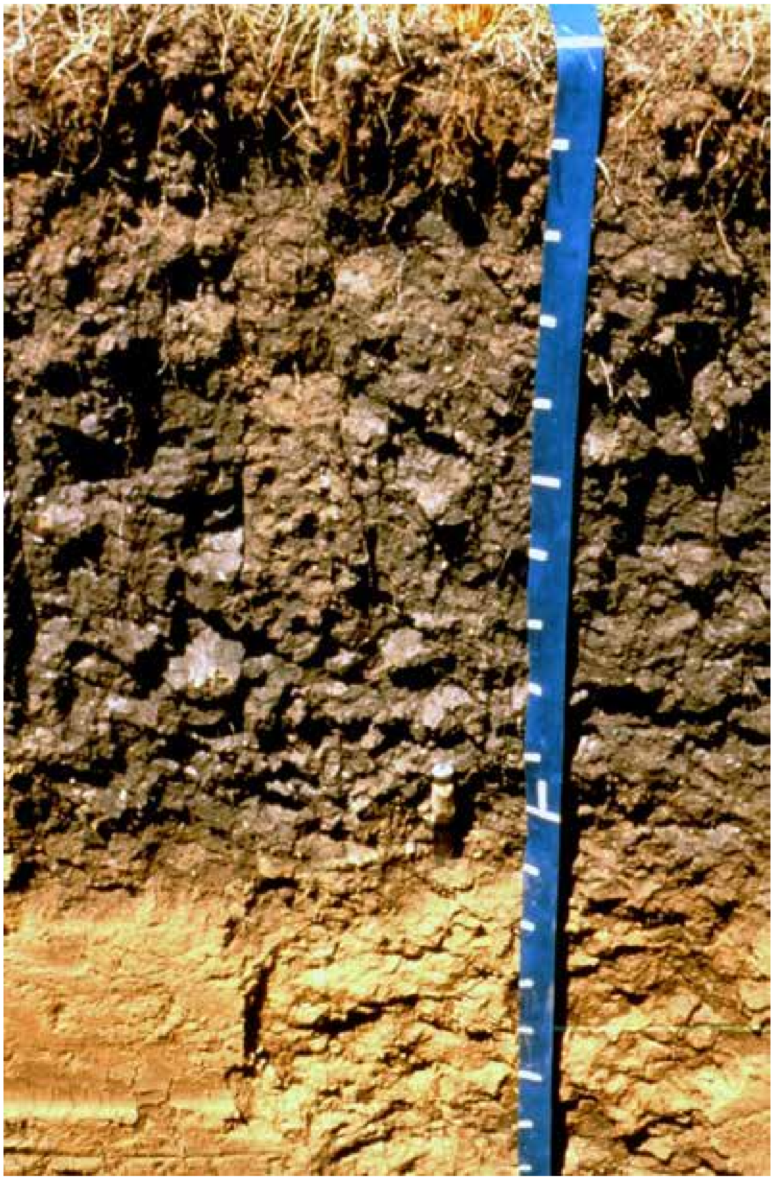
Dystruderts—These are the acid Uderts. They are derived dominantly from acid, fine textured materials and occur on alluvial plains, deltas, interfluves, and side slopes. Commonly, these soils are underlain by sediments high in bases. Some of these soils have diagnostic horizons, including argillic (clay accumulation), calcic (calcium carbonate accumulation), and gypsic (gypsum accumulation) subsoil horizons. In the United States, these soils occur in Texas and in the southeastern States, including the Alabama and Mississippi Blackland Prairie. They are used as cropland, pasture, or woodland. (Back to Uderts key)



Profile of a Dystrudert in Mississippi. This soil has a dark-colored, clayey ochric epipedon about 5 inches thick underlain by a reddish brown to yellowish brown, clayey argillic horizon that extends to a depth of about 40 inches. Below the argillic horizon is very pale brown to white, soft chalk and limestone. Scale is in inches.

Return to Dystruderts

Hapluderts—These soils have pH values that are dominantly above 5.0 (1:1 water) in the upper 50 cm. They typically have high base saturation, and some have diagnostic horizons, including argillic (clay accumulation) subsoil horizons. Hapluderts occur on uplands and in lower areas. They formed in a variety of fine textured parent material, including alluvium. In the United States, these soils occur in the Southeast, the northern Great Plains, and the Pacific Northwest. (Back to Uderts key)



Profile of a Hapludert in Texas. This soil has an ochric epipedon about 20 cm thick underlain by a cambic horizon that extends to a depth of about 100 cm. The cambic horizon has slickensides and wedge-shaped peds. This profile contains two distinct parent materials, as evidenced by a lithologic discontinuity at a depth of about 100 cm. The upper, darker part of the profile has a very high clay content and is subject to significant shrinking and swelling as it wets and dries. The lower, lighter-colored part of the profile (below the discontinuity) has a loamy texture and is much less susceptible to shrinking and swelling. Scale is in 10-cm increments.

Return to Hapluderts

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Teaching the
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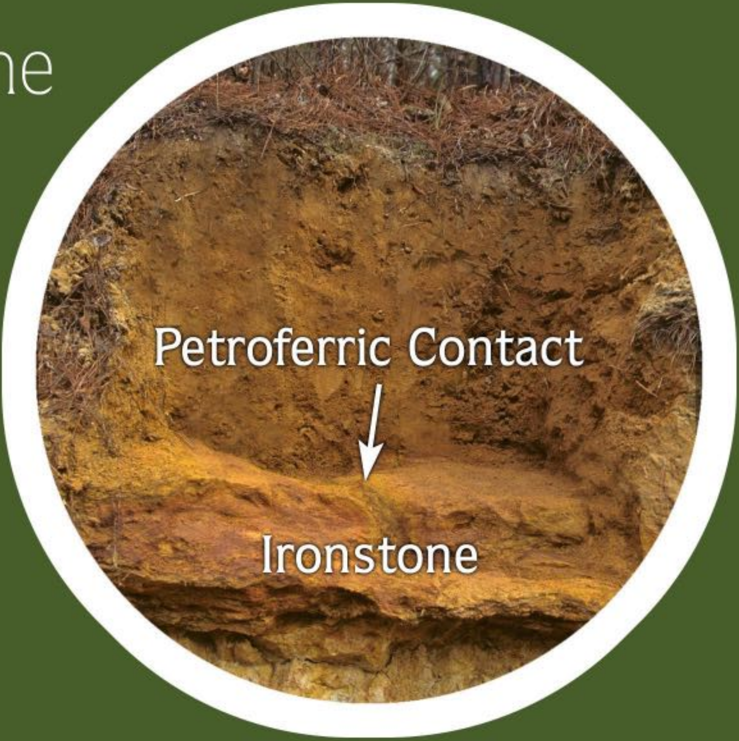
Concepts of
Soil Classification.



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