Soil Taxonomy

A Basic System of Soil Classification for Making and Interpreting Soil Surveys

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CHAPTER 3

Horizons and Characteristics Diagnostic for the Higher Categories

This chapter defines the horizons and characteristics of both mineral and organic soils. It is divided into three parts—horizons and characteristics diagnostic for mineral soils, characteristics diagnostic for organic soils, and horizons and characteristics diagnostic for both mineral and organic soils.

The horizons and characteristics defined below are not in a key format. The "required characteristics" for horizons or features, however, are arranged as a key. Some diagnostic horizons are mutually exclusive, and some are not. An umbric epipedon, for example, could not also be a mollic epipedon. A kandic horizon with clay films, however, could also meet the definition of an argillic horizon. The exclusions are stated in the horizon definitions.

Horizons and Characteristics Diagnostic for Mineral Soils

The criteria for some of the following horizons and characteristics, such as histic and folistic epipedons, can be met in organic soils. They are diagnostic, however, only for the mineral soils.

Diagnostic Surface Horizons: The Epipedon

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* as used here and in other places in this taxonomy includes fine stratification (5 mm or less thick) in unconsolidated sediments (eolian, alluvial, lacustrine, or marine) and saprolite derived from consolidated rocks in which the unweathered minerals and pseudomorphs of weathered minerals retain their relative positions to each other.

Any horizon may be at the surface of a truncated soil. The following section, however, is concerned with eight diagnostic horizons that have formed at or near the soil surface. These horizons can be covered by a surface mantle of new soil material. If the surface mantle has rock structure, the top of the epipedon is considered the soil surface unless the mantle meets the definition of buried soils in chapter 1. If the soil includes a buried soil, the epipedon, if any, is at the soil surface and the epipedon of the buried soil is considered a buried epipedon and is not considered in selecting taxa unless the keys specifically indicate buried horizons, such as those in Thapto-Histic subgroups. A soil with a mantle thick enough to have a buried soil has no epipedon if the soil has rock structure to the surface or has an Ap horizon less than 25 cm thick that is underlain by soil material with rock structure. The melanic epipedon (defined below) is unique among epipedons. It commonly forms in deposits of tephra and can receive fresh deposits of volcanic ash. Therefore, this horizon is permitted to have layers within and above the epipedon that are not part of the melanic epipedon.

A recent alluvial or eolian deposit that retains fine stratifications (5 mm or less thick) or an Ap horizon directly underlain by such stratified material is not included in the concept of the epipedon because time has not been sufficient for soil-forming processes to erase these transient marks of deposition and for diagnostic and accessory properties to develop.

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.

Anthropic Epipedon

The anthropic epipedon forms in human-altered or human-transported material (defined below). These epipedons form in soils which occur on anthropogenic landforms and microfeatures or which are higher than the adjacent soils by as much as or more than the thickness of the anthropic epipedon. They may also occur in excavated areas. Most anthropic epipedons contain artifacts other than those associated with agricultural practices (e.g., quicklime) and litter discarded by humans (e.g., aluminum cans). Anthropic epipedons may have an elevated phosphorus content from human additions of food debris (e.g., bones), compost, or manure, although a precise value is not required. Although anthropic epipedons formed at the soil surface, they may now be buried. Most anthropic epipedons occur in soils of gardens, middens (Hester et al., 1975), and urban areas, and most also meet the definition of another diagnostic mineral epipedon or subsurface horizon.

Required Characteristics

The anthropic epipedon consists of mineral soil material that shows evidence of the purposeful alteration of soil properties or of earth-surface features by human activity. The field evidence of alteration is significant and excludes agricultural practices such as shallow plowing or addition of amendments, such as lime or fertilizer.

The anthropic epipedon includes eluvial horizons that are at or near the soil surface, and it extends to the base of horizons that meet all the criteria shown below or it extends to the top of the first underlying diagnostic illuvial horizon (defined below as an argillic, kandic, natric, or spodic horizon). The anthropic epipedon meets *all* of the following:

1. When dry, has structural units with a diameter of 30 cm or less; *and*

2. Has rock structure, including fine stratifications (5 mm or less thick), in less than one-half of the volume of all parts; *and*

3. Formed in human-altered or human-transported material (defined below) on an anthropogenic landform or microfeature (defined below); *and either*:

   a. Directly overlies mine or dredged spoil material which has rock structure, a root-limiting layer, or a lithologic discontinuity with horizons that are not derived from human-altered or human-transported material (defined below); *or*

   b. Has *one or more* of the following throughout:

      (1) Artifacts, other than agricultural amendments (e.g., quicklime) and litter discarded by humans (e.g., aluminum cans); *or*

      (2) Midden material (i.e., eating and cooking waste and associated charred products); *or*

      (3) Anthraquic conditions; *and*

4. Has a minimum thickness that is *either*:

   a. The entire thickness of the soil above a root-limiting layer (defined in chapter 17) if one occurs within 25 cm of the soil surface; *or*

   b. 25 cm; *and*

5. Has an *n* value (defined below) of less than 0.7.

Folistic Epipedon

Required Characteristics

The folistic epipedon is a layer (one or more horizons) that is saturated for less than 30 days (cumulative) in normal years (and is not artificially drained) and *either*:

1. Consists of organic soil material that:

   a. Is 20 cm or more thick and either contains 75 percent or more (by volume) *Sphagnum* fibers or has a bulk density, moist, of less than 0.1 g/cm^3; *or*

   b. Is 15 cm or more thick; *or*

2. Is an Ap horizon that, when mixed to a depth of 25 cm, has an organic-carbon content (by weight) of:

   a. 16 percent or more if the mineral fraction contains 60 percent or more clay; *or*

   b. 8 percent or more if the mineral fraction contains no clay; *or*

   c. 8 + (clay percentage divided by 7.5) percent or more if the mineral fraction contains less than 60 percent clay.

Most folistic epipedons consist of organic soil material (defined in chapter 2). Item 2 provides for a folistic epipedon that is an Ap horizon consisting of mineral soil material.

Histic Epipedon

Required Characteristics

The histic epipedon is a layer (one or more horizons) that is characterized by saturation (for 30 days or more, cumulative) and reduction for some time during normal years (or is artificially drained) and *either*:

1. Consists of organic soil material that:

   a. Is 20 to 60 cm thick and either contains 75 percent or more (by volume) *Sphagnum* fibers or has a bulk density, moist, of less than 0.1 g/cm^3; *or*

   b. Is 20 to 40 cm thick; *or*

2. Is an Ap horizon that, when mixed to a depth of 25 cm, has an organic-carbon content (by weight) of:

   a. 16 percent or more if the mineral fraction contains 60 percent or more clay; *or*

   b. 8 percent or more if the mineral fraction contains no clay; *or*

   c. 8 + (clay percentage divided by 7.5) percent or more if the mineral fraction contains less than 60 percent clay.

Most histic epipedons consist of organic soil material (defined in chapter 2). Item 2 provides for a histic epipedon that is an Ap horizon consisting of mineral soil material. A histic epipedon consisting of mineral soil material can also be part of a mollic or umbric epipedon.

Melanic Epipedon

Required Characteristics

The melanic epipedon has *both* of the following:

1. An upper boundary at, or within 30 cm of, either the mineral soil surface or the upper boundary of an organic layer with andic soil properties (defined below), whichever is shallower; *and*

2. In layers with a cumulative thickness of 30 cm or more within a total thickness of 40 cm, *all* of the following:

   a. Andic soil properties throughout; *and*

b. A color value of 2.5 or less, moist, and chroma of 2 or less throughout; *and*

c. A melanic index (defined in the appendix) of 1.70 or less throughout; *and*

d. 6 percent or more organic carbon as a weighted average and 4 percent or more organic carbon in all layers.

Mollic Epipedon

Required Characteristics

The mollic epipedon consists of mineral soil material and, after mixing of the upper 18 cm of the mineral soil or of the whole mineral soil if its depth to a densic, lithic, or paralithic contact, a petrocalcic horizon, or a duripan (all defined below) is less than 18 cm, has the following properties:

1. When dry, *either or both*:

   a. Structural units with a diameter of 30 cm or less or secondary structure with a diameter of 30 cm or less; *or*

   b. A moderately hard or softer rupture-resistance class; *and*

2. Rock structure, including fine stratifications (5 mm or less thick), in less than one-half of the volume of all parts; *and*

3. *One* of the following:

   a. *Both* of the following:

      (1) Dominant color* with a value of 3 or less, moist, and of 5 or less, dry; *and*

      (2) Dominant color with chroma of 3 or less, moist; *or*

   b. A fine-earth fraction that has a calcium carbonate equivalent of 15 to 40 percent and colors with a value and chroma of 3 or less, moist; *or*

   c. A fine-earth fraction that has a calcium carbonate equivalent of 40 percent or more and a color value of 5 or less, moist; *and*

4. A base saturation (by NH_4OAc) of 50 percent or more throughout; *and*

5. An organic-carbon content of:

   a. 2.5 percent or more if the epipedon has a color value of 4 or 5, moist; *or*

   b. 0.6 percent (absolute) more than that of the C horizon (if one occurs) if the mollic epipedon has a color value less than 1 unit lower or chroma less than 2 units lower (both moist and dry) than the C horizon; *or*

   c. 0.6 percent or more and the epipedon does not meet the qualifications in 5-a or 5-b above; *and*

6. The minimum thickness of the epipedon is as follows:

   a. 25 cm if:

      (1) The texture class of the epipedon is loamy fine sand or coarser throughout; *or*

      (2) There are no underlying diagnostic horizons (defined below) and the organic-carbon content of the underlying materials decreases irregularly with increasing depth; *or*

      (3) *Any* of the following, if present, are 75 cm or more below the mineral soil surface:

         (a) The upper boundary of the shallowest of any identifiable secondary carbonates or a calcic horizon, petrocalcic horizon, duripan, or fragipan (defined below); *and/or*

         (b) The lower boundary of the deepest of an argillic, cambic, natric, oxic, or spodic horizon; *or*

   b. 10 cm if the epipedon has a texture class finer than loamy fine sand (when mixed) and it is directly above a densic, lithic, or paralithic contact, a petrocalcic horizon, or a duripan; *or*

   c. 18 to 25 cm and the thickness is one-third or more of the total thickness between the mineral soil surface and:

      (1) The upper boundary of the shallowest of any identifiable secondary carbonates or a calcic horizon, petrocalcic horizon, duripan, or fragipan; *and/or*

      (2) The lower boundary of the deepest of an argillic, cambic, natric, oxic, or spodic horizon; *or*

   d. 18 cm if none of the above conditions apply; *and*

7. Some part of the epipedon is moist for 90 days or more (cumulative) in normal years during times when the soil temperature at a depth of 50 cm below the soil surface is 5 ^{o}C or higher, if the soil is not irrigated; *and*

8. The *n* value (defined below) is less than 0.7.

Ochric Epipedon

The ochric epipedon fails to meet the definitions for any of the other seven epipedons because it is too thin or too dry, has too high a color value or chroma, contains too little organic carbon, has too high an *n* value or melanic index, or is both massive and hard or harder when dry. Many ochric epipedons have either a color value of 4 or more, moist, and 6 or more, dry, or chroma of 4 or more, or they include an A or Ap horizon that has both low color values and low chroma but is too thin to be recognized as a mollic or umbric epipedon (and has less than 15 percent calcium carbonate equivalent in the fine-earth fraction). Ochric epipedons also include horizons of organic

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* The concept of dominant color is defined in the *Soil Survey Manual* (Soil Survey Division Staff, 1993).

materials that are too thin to meet the requirements for a histic or folistic epipedon.

The ochric epipedon includes eluvial horizons that are at or near the soil surface, and it extends to the first underlying diagnostic illuvial horizon (defined below as an argillic, kandic, natric, or spodic horizon). If the underlying horizon is a B horizon of alteration (defined below as a cambic or oxic horizon) and there is no surface horizon that is appreciably darkened by humus, the lower limit of the ochric epipedon is the lower boundary of the plow layer or an equivalent depth (18 cm) in a soil that has not been plowed. Actually, the same horizon in an unplowed soil may be both part of the epipedon and part of the cambic horizon; the ochric epipedon and the subsurface diagnostic horizons are not all mutually exclusive. The ochric epipedon does not have rock structure and does not include finely stratified fresh sediments, nor can it be an Ap horizon directly overlying such deposits.

Plaggen Epipedon

The plaggen epipedon is a thick, human-made mineral surface layer that has been produced by long-continued manuring. A plaggen epipedon can be identified by several means. Commonly, it contains artifacts, such as brick and potsherds, throughout its thickness. There may be earthy fragments (i.e., clods) of diverse materials, such as black sand and light gray sand, as large as the size held by a spade. The plaggen epipedon normally shows spade marks at least in its lower part. It may also contain remnants of thin stratified beds of sand that were probably produced on the soil surface by beating rains and were later buried. A map unit delineation of soils with plaggen epipedons would tend to occur on straight-sided anthropogenic landforms that are higher than adjacent land surfaces by as much as or more than the thickness of the plaggen epipedon.

Required Characteristics

The plaggen epipedon consists of mineral soil material and meets *all* of the following:

1. It occurs in soils on locally raised landforms *and* contains *one or both* of the following:

    a. Artifacts, other than agricultural amendments (e.g., quicklime) and litter discarded by humans (e.g., aluminum cans); *or*

    b. Spade marks below a depth of 30 cm; *and*

2. It has colors with a value of 4 or less, moist, 5 or less, dry, and chroma of 2 or less; *and*

3. It has an organic-carbon content of 0.6 percent or more; *and*

4. It has a thickness of 50 cm or more of human-transported material (defined below); *and*

5. Some part of the epipedon is moist for 90 days or more (cumulative) in normal years during times when the soil temperature at a depth of 50 cm below the soil surface is 5 ^{o}C or higher, if the soil is not irrigated.

Umbric Epipedon

Required Characteristics

The umbric epipedon consists of mineral soil material and, after mixing of the upper 18 cm of the mineral soil or of the whole mineral soil if its depth to a densic, lithic, or paralithic contact, a petrocalcic horizon, or a duripan (all defined below) is less than 18 cm, has the following properties:

1. When dry, *either or both*:

    a. Structural units with a diameter of 30 cm or less or secondary structure with a diameter of 30 cm or less; *or*

    b. A moderately hard or softer rupture-resistance class; *and*

2. Rock structure, including fine stratifications (5 mm or less thick), in less than one-half of the volume of all parts; *and*

3. *Both* of the following:

    a. Dominant color* with a value of 3 or less, moist, and of 5 or less, dry; *and*

    b. Dominant color with chroma of 3 or less, moist; *and*

4. A base saturation (by NH_4OAc) of less than 50 percent in some or all parts; *and*

5. An organic-carbon content of:

    a. 0.6 percent (absolute) more than that of the C horizon (if one occurs) if the umbric epipedon has a color value less than 1 unit lower or chroma less than 2 units lower (both moist and dry) than the C horizon; *or*

    b. 0.6 percent or more and the epipedon does not meet the qualifications in 5-a above; *and*

6. The minimum thickness of the epipedon is as follows:

    a. 25 cm if:

        (1) The texture class of the epipedon is loamy fine sand or coarser throughout; *or*

        (2) There are no underlying diagnostic horizons (defined below) and the organic-carbon content of the underlying materials decreases irregularly with increasing depth; *or*

        (3) *Any* of the following, if present, are 75 cm or more below the mineral soil surface:

            (a) The upper boundary of the shallowest of any identifiable secondary carbonates or a calcic horizon, petrocalcic horizon, duripan, or fragipan (defined below); *and/or*

(b) The lower boundary of the deepest of an argillic, cambic, natric, oxic, or spodic horizon; *or*

b. 10 cm if the epipedon has a texture class finer than loamy fine sand (when mixed) and it is directly above a densic, lithic, or paralithic contact, a petrocalcic horizon, or a duripan; *or*

c. 18 to 25 cm and the thickness is one-third or more of the total thickness between the mineral soil surface and:

(1) The upper boundary of the shallowest of any identifiable secondary carbonates or a calcic horizon, petrocalcic horizon, duripan, or fragipan; *and/or*

(2) The lower boundary of the deepest of an argillic, cambic, natric, oxic, or spodic horizon; *or*

d. 18 cm if none of the above conditions apply; *and*

7. Some part of the epipedon is moist for 90 days or more (cumulative) in normal years during times when the soil temperature at a depth of 50 cm below the soil surface is 5 °C or higher, if the soil is not irrigated; *and*

8. The *n* value (defined below) is less than 0.7; *and*

9. The umbric epipedon does not have the artifacts, spade marks, and locally raised landforms that are characteristics of the plaggen epipedon.

Diagnostic Subsurface Horizons

The horizons described in this section form below the surface of the soil, although in some areas they form directly below a layer of leaf litter. They are composed of mineral soil material. They may be exposed at the surface by truncation of the soil. Some of these horizons are designated as B horizons by many, but not all, pedologists and others are generally designated as parts of A or E horizons.

Agric Horizon

The agric horizon is an illuvial horizon that has formed under cultivation and contains significant amounts of illuvial silt, clay, and humus.

Required Characteristics

The agric horizon is directly below an Ap horizon and has a thickness of 10 cm or more, and *either*:

1. 5 percent or more (by volume) wormholes, including coatings that are 2 mm or more thick and have a color value of 4 or less, moist, and chroma of 2 or less; *or*

2. 5 percent or more (by volume) lamellae that have a thickness of 5 mm or more and have a color value of 4 or less, moist, and chroma of 2 or less.

Albic Horizon

The albic horizon is an eluvial horizon, 1 cm or more thick, that has 85 percent or more (by volume) albic materials (defined below). It generally occurs below an A horizon but may be at the mineral soil surface. Under the albic horizon there generally is an argillic, cambic, kandic, natric, or spodic horizon or a fragipan (defined below). The albic horizon may lie between a spodic horizon and either a fragipan or an argillic horizon, or it may be between an argillic or kandic horizon and a fragipan. It may lie between a mollic epipedon and an argillic or natric horizon or between a cambic horizon and an argillic, kandic, or natric horizon or a fragipan. The albic horizon may separate horizons that, if they were together, would meet the requirements for a mollic epipedon. It may separate lamellae that together meet the requirements for an argillic horizon. These lamellae are not considered to be part of the albic horizon.

Anhydritic Horizon

The anhydritic horizon is a horizon in which anhydrite has accumulated through neoformation or transformation to a significant extent. It typically occurs as a subsurface horizon. It commonly occurs in conjunction with a salic horizon (defined below).

Required Characteristics

The anhydritic horizon meets *all* of the following requirements:

1. Is 15 cm or more thick; *and*

2. Is 5 percent or more (by weight) anhydrite; *and*

3. Has hue of 5Y, chroma (moist and dry) of 1 or 2, and value of 7 or 8; *and*

4. Has a product of thickness, in cm, multiplied by the anhydrite content (percent by weight) of 150 or more (thus, a horizon 30 cm thick that is 5 percent anhydrite qualifies as an anhydritic horizon); *and*

5. Has anhydrite as the predominant calcium sulfate mineral with gypsum either absent or present only in minor amounts.

Argillic Horizon

An argillic horizon is normally a subsurface horizon with a significantly higher percentage of phyllosilicate clay than the overlying soil material. It shows evidence of clay illuviation. The argillic horizon forms below the soil surface, but it may be exposed at the surface later by erosion.

Required Characteristics

1. All argillic horizons must meet *both* of the following requirements:

a. *One* of the following:

(1) If the argillic horizon meets the particle-size class criteria for coarse-loamy, fine-loamy, coarse-silty, fine-silty, fine, or very-fine or is loamy or clayey, including skeletal counterparts, it must be at least 7.5 cm thick or at least one-tenth as thick as the sum of the thickness of all overlying horizons, whichever is greater; *or*

(2) If the argillic horizon meets the sandy or sandy-skeletal particle-size criteria, it must be at least 15 cm thick; *or*

(3) If the argillic horizon is composed entirely of lamellae, the combined thickness of the lamellae that are 0.5 cm or more thick must be 15 cm or more; *and*

b. Evidence of clay illuviation in at least *one* of the following forms:

(1) Oriented clay bridging the sand grains; *or*

(2) Clay films lining pores; *or*

(3) Clay films on both vertical and horizontal surfaces of peds; *or*

(4) Thin sections with oriented clay bodies that are more than 1 percent of the section; *or*

(5) If the coefficient of linear extensibility is 0.04 or higher and the soil has distinct wet and dry seasons, then the ratio of fine clay to total clay in the illuvial horizon is greater by 1.2 times or more than the ratio in the eluvial horizon; *and*

2. If an eluvial horizon remains and there is no lithologic discontinuity between it and the illuvial horizon and no plow layer directly above the illuvial layer, then the illuvial horizon must contain more total clay than the eluvial horizon within a vertical distance of 30 cm or less, as follows:

a. If any part of the eluvial horizon has less than 15 percent total clay in the fine-earth fraction, the argillic horizon must contain at least 3 percent (absolute) more clay (10 percent versus 13 percent, for example); *or*

b. If the eluvial horizon has 15 to 40 percent total clay in the fine-earth fraction, the argillic horizon must have at least 1.2 times more clay than the eluvial horizon; *or*

c. If the eluvial horizon has 40 percent or more total clay in the fine-earth fraction, the argillic horizon must contain at least 8 percent (absolute) more clay (42 percent versus 50 percent, for example).

Calcic Horizon

The calcic horizon is an illuvial horizon in which secondary calcium carbonate or other carbonates have accumulated to a significant extent.

Required Characteristics

The calcic horizon:

1. Is 15 cm or more thick; *and*

2. Has *one or more* of the following:

a. 15 percent or more (by weight, fine-earth fraction) $CaCO_3$ equivalent, and its $CaCO_3$ equivalent is 5 percent or more (absolute) higher than that of an underlying horizon; *or*

b. 15 percent or more (by weight, fine-earth fraction) $CaCO_3$ equivalent and 5 percent or more (by volume) identifiable secondary carbonates; *or*

c. 5 percent or more (by weight, fine-earth fraction) calcium carbonate equivalent and:

(1) Has less than 18 percent clay in the fine-earth fraction; *and*

(2) Meets the criteria for a sandy, sandy-skeletal, coarse-loamy, or loamy-skeletal particle-size class[†] (defined in chapter 17); *and*

(3) Has 5 percent or more (by volume) identifiable secondary carbonates or a calcium carbonate equivalent (by weight, fine-earth fraction) that is 5 percent or more (absolute) higher than that of an underlying horizon; *and*

3. Is not cemented or indurated in any part by carbonates, with or without other cementing agents, or is cemented in some part and the cemented part satisfies *one* of the following:

a. It is characterized by so much lateral discontinuity that roots can penetrate through noncemented zones or along vertical fractures with a horizontal spacing of less than 10 cm; *or*

b. The cemented layer is less than 1 cm thick and consists of a laminar cap underlain by a lithic or paralithic contact; *or*

c. The cemented layer is less than 10 cm thick.

Cambic Horizon

A cambic horizon is the result of physical alterations, chemical transformations, or removals or of a combination of two or more of these processes.

Required Characteristics

The cambic horizon is an altered horizon 15 cm or more thick. If it is composed of lamellae, the combined thickness of the lamellae must be 15 cm or more. In addition, the cambic horizon must meet *all* of the following:

[†] Particle-size classes are used in this required characteristic as a convenient proxy for many possible combinations of USDA texture class and texture modifier and do not imply that the soil meeting this option for the diagnostic horizon also meets the particle-size class criteria in the family classification.

1. Has a texture class of very fine sand, loamy very fine sand, or finer; *and*

2. Shows evidence of alteration in *one* of the following forms:

a. Aquic conditions within 50 cm of the soil surface or artificial drainage and *all* of the following:

(1) Soil structure or the absence of rock structure, including fine stratifications (5 mm or less thick), in more than one-half of the volume; *and*

(2) Colors that do not change on exposure to air; *and*

(3) Dominant color, moist, on faces of peds or in the matrix as follows:

(a) Value of 3 or less and neutral colors with no hue (N) and zero chroma; *or*

(b) Value of 4 or more and chroma of 1 or less; *or*

(c) Any value, chroma of 2 or less, and redox concentrations; *or*

b. Does not have the combination of aquic conditions within 50 cm of the soil surface or artificial drainage and colors, moist, as defined in item 2-a-(3) above, and has soil structure or the absence of rock structure, including fine stratifications (5 mm or less thick), in more than one-half of the volume and *one or more* of the following properties:

(1) Higher chroma, higher value, redder hue, or higher clay content than the underlying horizon or an overlying horizon; *or*

(2) Evidence of the removal of carbonates or gypsum; *and*

3. Has properties that do not meet the requirements for an anthropic, histic, folistic, melanic, mollic, plaggen, or umbric epipedon, a duripan or fragipan, or an argillic, calcic, gypsic, natric, oxic, petrocalcic, petrogypsic, placic, salic, spodic, or sulfuric horizon; *and*

4. Is not part of an Ap horizon and does not have a brittle manner of failure in more than 60 percent of the matrix.

Duripan

A duripan is a silica-cemented subsurface horizon with or without auxiliary cementing agents. It can occur in conjunction with a petrocalcic horizon.

Required Characteristics

A duripan must meet *all* of the following requirements:

1. The pan is cemented or indurated in more than 50 percent of the volume of some horizon; *and*

2. The pan shows evidence of the accumulation of opal or other forms of silica, such as laminar caps, coatings, lenses, partly filled interstices, bridges between sand-sized grains, or coatings on rock and pararock fragments; *and*

3. Less than 50 percent of the volume of air-dry fragments slakes in 1N HCl even during prolonged soaking, but more than 50 percent slakes in concentrated KOH or NaOH or in alternating acid and alkali; *and*

4. Because of lateral continuity, roots can penetrate the pan only along vertical fractures with a horizontal spacing of 10 cm or more.

Fragipan

Required Characteristics

To be identified as a fragipan, a layer must have *all* of the following characteristics:

1. The layer is 15 cm or more thick; *and*

2. The layer shows evidence of pedogenesis within the horizon or, at a minimum, on the faces of structural units; *and*

3. The layer has very coarse prismatic, columnar, or blocky structure of any grade, has weak structure of any size, or is massive. Separations between structural units that allow roots to enter have an average spacing of 10 cm or more on the horizontal dimensions; *and*

4. Air-dry fragments of the natural soil fabric, 5 to 10 cm in diameter, from more than 50 percent of the layer slake when they are submerged in water; *and*

5. The layer has, in 60 percent or more of the volume, a firm or firmer rupture-resistance class, a brittle manner of failure at or near field capacity, and virtually no roots; *and*

6. The layer is not effervescent (in dilute HCl).

Glossic Horizon

The glossic (Gr. *glossa*, tongue) horizon develops as a result of the degradation of an argillic, kandic, or natric horizon from which clay and free iron oxides are removed.

Required Characteristics

The glossic horizon is 5 cm or more thick and consists of:

1. An eluvial part (albic materials, defined below), which constitutes 15 to 85 percent (by volume) of the glossic horizon; *and*

2. An illuvial part, i.e., remnants (pieces) of an argillic, kandic, or natric horizon (defined below).

Gypsic Horizon

The gypsic horizon is a horizon in which gypsum has accumulated or been transformed to a significant extent. It typically occurs as a subsurface horizon, but it may occur at the surface in some soils.

Required Characteristics

A gypsic horizon meets *all* of the following requirements:

1. Is 15 cm or more thick; *and*

2. Is not cemented by gypsum, with or without other cementing agents; is cemented and the cemented parts are less than 5 mm thick; or is cemented but, because of lateral discontinuity, roots can penetrate along vertical fractures with a horizontal spacing of less than 10 cm; *and*

3. Is 5 percent or more (by weight) gypsum and has 1 percent or more (by volume) visible secondary gypsum that has either accumulated or been transformed; *and*

4. Has a product of thickness, in cm, multiplied by the gypsum content (percent by weight) of 150 or more. Thus, a horizon 30 cm thick that is 5 percent gypsum qualifies as a gypsic horizon if it is 1 percent or more (by volume) visible gypsum and any cementation is as described in 2 above.

Kandic Horizon

Required Characteristics

The kandic horizon:

1. Is a vertically continuous subsurface horizon that underlies a coarser textured surface horizon. The minimum thickness of the surface horizon is 18 cm after mixing or 5 cm if the textural transition to the kandic horizon is abrupt and there is no densic, lithic, paralithic, or petroferric contact (defined below) within 50 cm of the mineral soil surface; *and*

2. Has its upper boundary:

a. At the point where the clay percentage in the fine-earth fraction is increasing with depth within a vertical distance of 15 cm and is *either*:

(1) 4 percent or more (absolute) higher than that in the overlying horizon if that horizon has less than 20 percent total clay in the fine-earth fraction; *or*

(2) 20 percent or more (relative) higher than that in the overlying horizon if that horizon has 20 to 40 percent total clay in the fine-earth fraction; *or*

(3) 8 percent or more (absolute) higher than that in the overlying horizon if that horizon has more than 40 percent total clay in the fine-earth fraction; *and*

b. At a depth:

(1) Between 100 cm and 200 cm from the mineral soil surface if the upper 100 cm has a texture class (fine-earth fraction) of coarse sand, sand, fine sand, loamy coarse sand, loamy sand, or loamy fine sand throughout; *or*

(2) Within 100 cm from the mineral soil surface if the clay content in the fine-earth fraction of the overlying horizon is 20 percent or more; *or*

(3) Within 125 cm from the mineral soil surface for all other soils; *and*

3. Has a thickness of *either*:

a. 30 cm or more; *or*

b. 15 cm or more if there is a densic, lithic, paralithic, or petroferric contact within 50 cm of the mineral soil surface and the kandic horizon constitutes 60 percent or more of the vertical distance between a depth of 18 cm and the contact; *and*

4. Has a texture class of loamy very fine sand or finer; *and*

5. Has an apparent CEC of 16 cmol(+) or less per kg clay (by 1N NH_4OAc pH 7) and an apparent ECEC of 12 cmol(+) or less per kg clay (sum of bases extracted with 1N NH_4OAc pH 7 plus 1N KCl-extractable Al) in 50 percent or more of its thickness between the point where the clay increase requirements are met and either a depth of 100 cm below that point or a densic, lithic, paralithic, or petroferric contact if shallower. (The percentage of clay is either measured by the pipette method or estimated to be 2.5 times [percent water retained at 1500 kPa tension minus percent organic carbon], whichever is higher, but no more than 100); *and*

6. Has a regular decrease in organic-carbon content with increasing depth, no fine stratification, and no overlying layers more than 30 cm thick that have fine stratification and/or an organic-carbon content that decreases irregularly with increasing depth.

Natric Horizon

A natric horizon is an illuvial horizon that is normally present in the subsurface and has a significantly higher percentage of silicate clay than the overlying horizons. It shows evidence of clay illuviation that has been accelerated by the dispersive properties of sodium.

Required Characteristics

The natric horizon:

1. Meets *one* of the following thickness requirements:

a. If the horizon meets the particle-size class criteria for coarse-loamy, fine-loamy, coarse-silty, fine-silty, fine, or very-fine or is loamy or clayey, including skeletal counterparts, it must be at least 7.5 cm thick or at least one-tenth as thick as the sum of the thickness of all overlying horizons, whichever is greater; *or*

b. If the horizon meets sandy or sandy-skeletal particle-size class criteria, it must be at least 15 cm thick; *or*

c. If the horizon is composed entirely of lamellae, the combined thickness of the lamellae that are 0.5 cm or more thick must be 15 cm or more; *and*

2. Has evidence of clay illuviation in at least *one* of the following forms:

a. Oriented clay bridging the sand grains; *or*

b. Clay films lining pores; *or*

c. Clay films on both vertical and horizontal surfaces of peds; *or*

d. Thin sections with oriented clay bodies that are more than 1 percent of the section; *or*

e. If the coefficient of linear extensibility is 0.04 or higher and the soil has distinct wet and dry seasons, then the ratio of fine clay to total clay in the illuvial horizon is greater by 1.2 times or more than the ratio in the eluvial horizon; *and*

3. If an eluvial horizon remains and there is no lithologic discontinuity between it and the illuvial horizon and no plow layer directly above the illuvial horizon, then the illuvial horizon must contain more total clay than the eluvial horizon within a vertical distance of 30 cm or less, as follows:

a. If any part of the eluvial horizon has less than 15 percent total clay in the fine-earth fraction, the illuvial horizon must contain at least 3 percent (absolute) more clay (10 percent versus 13 percent, for example); *or*

b. If the eluvial horizon has 15 to 40 percent total clay in the fine-earth fraction, the illuvial horizon must have at least 1.2 times more clay than the eluvial horizon; *or*

c. If the eluvial horizon has 40 percent or more total clay in the fine-earth fraction, the illuvial horizon must contain at least 8 percent (absolute) more clay (42 percent versus 50 percent, for example); *and*

4. Has *either:*

a. Columnar or prismatic structure in some part (generally the upper part), which may part to blocky structure; *or*

b. Both blocky structure and eluvial materials, which contain uncoated silt or sand grains and extend more than 2.5 cm into the horizon; *and*

5. Has *either:*

a. An exchangeable sodium percentage (ESP) of 15 percent or more (or a sodium adsorption ratio [SAR] of 13 or more) in one or more horizons within 40 cm of its upper boundary; *or*

b. More exchangeable magnesium plus sodium than calcium plus extractable acidity (at pH 8.2) in one or more horizons within 40 cm of its upper boundary *and* the ESP is 15 or more (or the SAR is 13 or more) in one or more horizons within 200 cm of the mineral soil surface.

Ortstein

Required Characteristics

Ortstein has *all* of the following:

1. Consists of spodic materials (defined below); *and*

2. Is in a layer that is 50 percent or more cemented; *and*

3. Is 25 mm or more thick.

Continuous ortstein is 90 percent or more cemented and has lateral continuity. Because of this continuity, roots can penetrate only along vertical fractures with a horizontal spacing of 10 cm or more.

Oxic Horizon

Required Characteristics

The oxic horizon is a subsurface horizon that does not have andic soil properties (defined below) and has *all* of the following characteristics:

1. A thickness of 30 cm or more; *and*

2. A texture class of sandy loam or finer in the fine-earth fraction; *and*

3. Less than 10 percent weatherable minerals in the 0.05 to 0.2 mm fraction; *and*

4. Rock structure in less than 5 percent of its volume, unless the lithorelicts with weatherable minerals are coated with sesquioxides; *and*

5. Within a vertical distance of 15 cm or more from the upper boundary (i.e, diffuse), a clay increase, with increasing depth, of:

a. Less than 4 percent (absolute) in its fine-earth fraction if the fine-earth fraction of the overlying horizon contains less than 20 percent clay; *or*

b. Less than 20 percent (relative) in its fine-earth fraction if the fine-earth fraction of the overlying horizon contains 20 to 40 percent clay; *or*

c. Less than 8 percent (absolute) in its fine-earth fraction if the fine-earth fraction of the overlying horizon contains 40 percent or more clay); *and*

6. An apparent CEC of 16 cmol(+) or less per kg clay (by 1N NH_4OAc pH 7) and an apparent ECEC of 12 cmol(+) or less per kg clay (sum of bases extracted with 1N NH_4OAc pH 7 plus 1N KCl-extractable Al). (The percentage of clay is either measured

by the pipette method or estimated to be 3 times [percent water retained at 1500 kPa tension minus percent organic carbon], whichever value is higher, but no more than 100.)

Petrocalcic Horizon

The petrocalcic horizon is an illuvial horizon in which secondary calcium carbonate or other carbonates have accumulated to the extent that the horizon is cemented or indurated.

Required Characteristics

A petrocalcic horizon must meet the following requirements:

1. The horizon is cemented or indurated by carbonates, with or without silica or other cementing agents; *and*

2. Because of lateral continuity, roots can penetrate only along vertical fractures with a horizontal spacing of 10 cm or more; *and*

3. The horizon has a thickness of:

   a. 10 cm or more; *or*

   b. 1 cm or more if it consists of a laminar cap directly underlain by bedrock.

Petrogypsic Horizon

The petrogypsic horizon is a horizon in which visible secondary gypsum has accumulated or has been transformed. The horizon is cemented (i.e., extremely weakly cemented through indurated cementation classes), and the cementation is both laterally continuous and root limiting, even when the soil is moist. The horizon typically occurs as a subsurface horizon, but it may occur at the surface in some soils.

Required Characteristics

A petrogypsic horizon meets *all* of the following requirements:

1. Is cemented or indurated by gypsum, with or without other cementing agents; *and*

2. Because of lateral continuity, can be penetrated by roots only along vertical fractures with a horizontal spacing of 10 cm or more; *and*

3. Is 5 mm or more thick; *and*

4. Is 40 percent or more (by weight) gypsum.

Placic Horizon

The placic (Gr. base of *plax*, flat stone; meaning a thin cemented pan) horizon is a thin, black to dark reddish pan that is cemented by iron (or iron and manganese) and organic matter.

Required Characteristics

A placic horizon must meet the following requirements:

1. The horizon is cemented or indurated with iron or iron and manganese and organic matter, with or without other cementing agents; *and*

2. Because of lateral continuity, roots can penetrate only along vertical fractures with a horizontal spacing of 10 cm or more; *and*

3. The horizon has a minimum thickness of 1 mm and, where associated with spodic materials (defined below), is less than 25 mm thick.

Salic Horizon

A salic horizon is a horizon of accumulation of salts that are more soluble than gypsum in cold water.

Required Characteristics

A salic horizon is 15 cm or more thick and has, for 90 consecutive days or more in normal years:

1. An electrical conductivity (EC) equal to or greater than 30 dS/m in the water extracted from a saturated paste; *and*

2. A product of the EC, in dS/m, and thickness, in cm, equal to 900 or more.

Sombric Horizon

A sombric (F. *sombre*, dark) horizon is a subsurface horizon in mineral soils that has formed under free drainage. It contains illuvial humus that is neither associated with aluminum, as is the humus in the spodic horizon, nor dispersed by sodium, as is common in the natric horizon. Consequently, the sombric horizon does not have the high cation-exchange capacity in its clay that characterizes a spodic horizon and does not have the high base saturation of a natric horizon. It does not underlie an albic horizon.

Sombric horizons are thought to be restricted to the cool, moist soils of high plateaus and mountains in tropical or subtropical regions. Because of strong leaching, their base saturation is low (less than 50 percent by NH_4OAc).

The sombric horizon has a lower color value or chroma, or both, than the overlying horizon and commonly contains more organic matter. It may have formed in an argillic, cambic, or oxic horizon. If peds are present, the dark colors are most pronounced on surfaces of peds.

In the field a sombric horizon is easily mistaken for a buried A horizon. It can be distinguished from some buried epipedons by lateral tracing. In thin sections the organic matter of a sombric horizon appears more concentrated on peds and in pores than uniformly dispersed throughout the matrix.

Spodic Horizon

A spodic horizon is an illuvial layer with 85 percent or more spodic materials (defined below).

Required Characteristics

A spodic horizon is normally a subsurface horizon underlying an O, A, Ap, or E horizon. It may, however, meet the definition of an umbric epipedon.

A spodic horizon must have 85 percent or more spodic materials in a layer 2.5 cm or more thick that is not part of any Ap horizon.

Diagnostic Soil Characteristics for Mineral Soils

Diagnostic soil characteristics are features of the soil that are used in various places in the keys or in the definitions of diagnostic horizons.

Abrupt Textural Change

An abrupt textural change is a specific kind of change that may occur between an epipedon composed of mineral soil material or an eluvial horizon and an underlying argillic, glossic, kandic, or natric horizon. It is characterized by a considerable increase in clay content within a very short vertical distance in the zone of contact.

In soils that have an abrupt textural change, there normally is no transitional horizon between a mineral epipedon or an eluvial horizon and an argillic, glossic, kandic, or natric horizon, or the transitional horizon is too thin to be sampled. Some soils, however, have a glossic horizon or interfingering of albic materials (defined below) into parts of an argillic, kandic, or natric horizon. The upper boundary of such a horizon is irregular or even discontinuous. Sampling this mixture as a single horizon might create the impression of a relatively thick transitional horizon, whereas the thickness of the actual transition at the contact may be no more than 1 mm.

Required Characteristics

An abrupt textural change meets *both* of the following requirements:

1. The noncarbonate clay content in the fine-earth fraction of the argillic, glossic, kandic, or natric horizon is at least 8 percent (by weight); *and*

2. The noncarbonate clay content in the fine-earth fraction of the argillic, glossic, kandic, or natric horizon must *either*:

   a. Double within a vertical distance of 7.5 cm or less if the clay content, in the fine-earth fraction of the epipedon composed of mineral soil material or the eluvial horizon, is less than 20 percent (e.g., an increase from 4 to 8 percent); *or*

   b. Increase by 20 percent or more (absolute) within a vertical distance of 7.5 cm or less (e.g., an increase from 22 to 42 percent) and the clay content in some part of the horizon is 2 times or more the amount contained in the overlying epipedon composed of mineral soil material or the eluvial horizon.

DIA

Albic Materials

Albic (L. *albus*, white) materials are soil materials with a color that is largely determined by the color of primary sand and silt particles rather than by the color of their coatings. This definition implies that clay and/or free iron oxides have been removed from the materials or that the oxides have been segregated to such an extent that the color of the materials is largely determined by the color of the primary particles.

Required Characteristics

Albic materials have *one* of the following colors:

1. Chroma of 2 or less; *and either*

   a. A color value of 3, moist, and 6 or more, dry; *or*

   b. A color value of 4 or more, moist, and 5 or more, dry; *or*

2. Chroma of 3 or less; *and either*

   a. A color value of 6 or more, moist; *or*

   b. A color value of 7 or more, dry; *or*

3. Chroma that is controlled by the color of uncoated grains of silt or sand, hue of 5YR or redder, and the color values listed in item 1-a or 1-b above.

Relatively unaltered layers of light colored sand, volcanic ash, or other materials deposited by wind or water are not considered albic materials, although they may have the same color and apparent morphology. These deposits are parent materials that are not characterized by the removal of clay and/or free iron and do not overlie an illuvial horizon or other soil horizon, except for a buried soil. Light-colored krotovinas or filled root channels should be considered albic materials only if they have no fine stratifications or lamellae, if any sealing along the krotovina walls has been destroyed, and if these intrusions have been leached of free iron oxides and/or clay after deposition.

Andic Soil Properties

Andic soil properties commonly form during weathering of tephra or other parent materials containing a significant content of volcanic glass. Soils that are in cool, humid climates and have abundant organic carbon, however, may develop andic soil properties without the influence of volcanic glass. A suite of

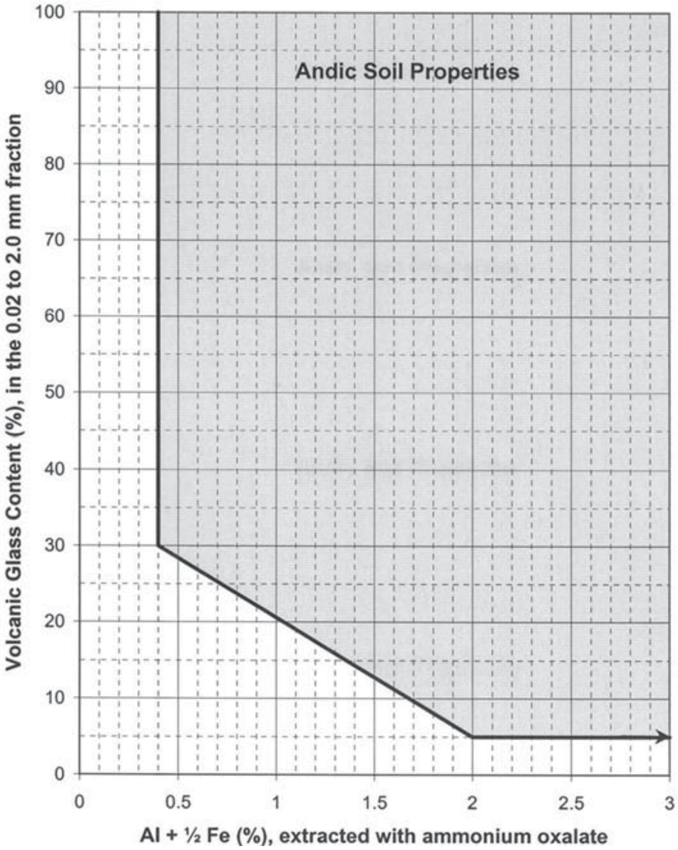

Figure 1.—Soils that are plotted in the shaded area meet the andic soil properties criteria c, d, and e under item 3 of the required characteristics. To qualify as soils with andic properties, the soils must also meet the listed requirements for organic-carbon content, phosphate retention, and particle-size distribution.

glass and glass-coated minerals rich in silica is termed volcanic glass in this taxonomy. These minerals are relatively soluble and undergo fairly rapid transformation when the soils are moist. Andic soil properties represent a stage in transition where weathering and transformation of primary alumino-silicates (e.g., volcanic glass) have proceeded only to the point of the formation of short-range-order materials, such as allophane, imogolite, and ferrihydrite, or of metal-humus complexes. The concept of andic soil properties includes moderately weathered soil material, rich in short-range-order materials or metal-humus complexes, or both, with or without volcanic glass (required characteristic 2) and weakly weathered soil, less rich in short-range-order materials with volcanic glass (required characteristic 3).

Relative amounts of allophane, imogolite, ferrihydrite, or metal-humus complexes in the colloidal fraction are inferred from laboratory analyses of aluminum, iron, and silica extracted by ammonium oxalate, and from phosphate retention. Soil scientists may use smeariness or pH in 1N sodium fluoride (NaF) as field indicators of andic soil properties. *Volcanic glass content* is the percent volcanic glass (by grain count) in the coarse silt and sand (0.02 to 2.0 mm) fraction. Most soil materials with andic soil properties consist of mineral soil materials, but some are organic soil materials with less than 25 percent organic carbon.

Required Characteristics

Soil materials with andic soil properties must have a fine-earth fraction that meets the following requirements:

1. Less than 25 percent organic carbon (by weight) and *one or both* of the following:

2. *All* of the following:

a. Bulk density, measured at 33 kPa water retention, of 0.90 g/cm^3 or less; *and*

b. Phosphate retention of 85 percent or more; *and*

c. Al plus ½ Fe content (by ammonium oxalate) equal to 2.0 percent or more; *or*

3. *All* of the following:

a. 30 percent or more of the fine-earth fraction is 0.02 to 2.0 mm in size; *and*

b. Phosphate retention of 25 percent or more; *and*

c. Al plus ½ Fe content (by ammonium oxalate) equal to 0.4 percent or more; *and*

d. Volcanic glass content of 5 percent or more; *and*

e. [(Al plus ½ Fe content, percent) times (15.625)] + [volcanic glass content, percent] = 36.25 or more.

The shaded area in figure 1 illustrates criteria 3c, 3d, and 3e.

Anhydrous Conditions

Anhydrous (Gr. *anydros*, waterless) conditions refer to the moisture condition of soils in very cold deserts and other areas with permafrost (often dry permafrost). These soils typically have low precipitation (usually less than 50 mm water equivalent per year) and a moisture content of less than 3 percent by weight. Anhydrous soil conditions are similar to the aridic (torric) soil moisture regimes (defined below), except that the soil temperature at 50 cm is less than 5 °C throughout the year in the soil layers with these conditions.

Required Characteristics

Soils with anhydrous conditions have a mean annual soil temperature of 0 °C or colder. The layer from 10 to 70 cm below the soil surface has a soil temperature of less than 5 °C throughout the year *and* this layer:

1. Includes no ice-impregnated permafrost; *and*

2. Is dry (water held at 1500 kPa or more) in one-half or more of the soil for one-half or more of the time the layer has a soil temperature above 0 °C; *or*

3. Has a rupture-resistance class of loose to slightly hard throughout when the soil temperature is 0 °C or colder, except where a cemented pedogenic horizon occurs.

Coefficient of Linear Extensibility (COLE)

The coefficient of linear extensibility (COLE) is the ratio of the difference between the moist length and dry length of a clod to its dry length. It is (Lm - Ld)/Ld, where Lm is the length at 33 kPa tension and Ld is the length when dry. COLE can be calculated from the differences in bulk density of the clod when moist and when dry. An estimate of COLE can be calculated in the field by measuring the distance between two pins in a clod of undisturbed soil at field capacity and again after the clod has dried. COLE does not apply if the shrinkage is irreversible.

Durinodes

Durinodes (L. *durus*, hard, and *nodus*, knot) are weakly cemented to indurated nodules or concretions with a diameter of 1 cm or more. The cement is SiO_2, presumably opal and microcrystalline forms of silica. Durinodes break down in hot concentrated KOH after treatment with HCl to remove carbonates but do not break down with concentrated HCl alone. Dry durinodes do not slake appreciably in water, but prolonged soaking can result in spalling of very thin platelets. Durinodes are firm or firmer and brittle when wet, both before and after treatment with acid. Some durinodes are roughly concentric when viewed in cross section, and concentric stringers of opal are visible under a hand lens.

Fragic Soil Properties

Fragic soil properties are the essential properties of a fragipan. They have neither the layer thickness nor volume requirements for the fragipan. Fragic soil properties are in subsurface horizons, although they can be at or near the surface in truncated soils. Aggregates with fragic soil properties have a firm or firmer rupture-resistance class and a brittle manner of failure when soil water is at or near field capacity. Air-dry fragments of the natural fabric, 5 to 10 cm in diameter, slake when they are submerged in water. Aggregates with fragic soil properties show evidence of pedogenesis, including one or more of the following: oriented clay within the matrix or on faces of peds, redoximorphic features within the matrix or on faces of peds, strong or moderate soil structure, and coatings of albic materials or uncoated silt and sand grains on faces of peds or in seams. Peds with these properties are considered to have fragic soil properties regardless of whether or not the density and brittleness are pedogenic.

Soil aggregates with fragic soil properties must:

1. Show evidence of pedogenesis within the aggregates or, at a minimum, on the faces of the aggregates; *and*

2. Slake when air-dry fragments of the natural fabric, 5 to 10 cm in diameter, are submerged in water; *and*

3. Have a firm or firmer rupture-resistance class and a brittle manner of failure when soil water is at or near field capacity; *and*

4. Restrict the entry of roots into the matrix when soil water is at or near field capacity.

Free Carbonates

The term “free carbonates” is used in the definitions of a number of taxa, is used as a criterion for the isotic mineralogy class, and is mentioned in the discussion of chemical analyses in the appendix. It refers to soil carbonates that are uncoated or unbound and that effervesce visibly or audibly when treated with cold, dilute HCl. The term “free carbonates” is nearly synonymous with the term “calcareous.” Soils that have free carbonates generally have calcium carbonate as a common mineral, although sodium and magnesium carbonates are also included in this concept. Soils or horizons with free carbonates may have inherited the carbonate compounds from parent materials without any translocation or transformation processes acting on them. There is no implication of pedogenesis in the concept of free carbonates, as there is in identifiable secondary carbonates (defined below), although most forms of secondary carbonates are freely effervescent.

Identifiable Secondary Carbonates

The term “identifiable secondary carbonates” is used in the definitions of a number of taxa. It refers to translocated authigenic calcium carbonate that has been precipitated in place from the soil solution rather than inherited from a soil parent material, such as calcareous loess or limestone residuum.

Identifiable secondary carbonates either may disrupt the soil structure or fabric, forming masses, nodules, concretions, or spheroidal aggregates (white eyes) that are soft and powdery when dry, or may be present as coatings in pores, on structural faces, or on the undersides of rock or pararock fragments. If present as coatings, the secondary carbonates cover a significant part of the surfaces. Commonly, they coat all of the surfaces to a thickness of 1 mm or more. If little calcium carbonate is present in the soil, however, the surfaces may be only partially coated. The coatings must be thick enough to be visible when moist. Some horizons are entirely engulfed by carbonates. The color of these horizons is largely determined by the carbonates. The carbonates in these horizons are within the concept of identifiable secondary carbonates.

The filaments commonly seen in a dry calcareous horizon are within the meaning of identifiable secondary carbonates if the filaments are thick enough to be visible when the soil is moist. Filaments commonly branch on structural faces.

Interfingering of Albic Materials

The term “interfingering of albic materials” refers to albic materials that penetrate 5 cm or more into an underlying argillic, kandic, or natric horizon along vertical and, to a lesser degree, horizontal faces of peds. There need not be a continuous overlying albic horizon. The albic materials constitute less than 15 percent of the layer that they penetrate, but they form continuous skeletans (ped coatings of clean silt or sand defined by Brewer, 1976) 1 mm or more thick on the vertical faces of peds, which means a total width of 2 mm or more between abutting peds. Because quartz is such a common constituent of silt and sand, these skeletans are usually light gray when moist and nearly white when dry, but their color is determined in large part by the color of the sand or silt fraction.

Required Characteristics

Interfingering of albic materials is recognized if albic materials:

1. Penetrate 5 cm or more into an underlying argillic, kandic, or natric horizon; *and*

2. Are 2 mm or more thick between vertical faces of abutting peds; *and*

3. Constitute less than 15 percent (by volume) of the layer that they penetrate.

Lamellae

Lamellae (lamella, if singular) are illuvial horizons less than 7.5 cm thick. Each lamella contains an accumulation of oriented silicate clay on or bridging sand and silt grains (and rock fragments if any are present). A lamella has more silicate clay than the overlying eluvial horizon.

Required Characteristics

A lamella is an illuvial horizon less than 7.5 cm thick formed in unconsolidated regolith more than 50 cm thick. Each lamella contains an accumulation of oriented silicate clay on or bridging the sand and silt grains (and rock fragments if any are present). Each lamella is required to have more silicate clay than the overlying eluvial horizon.

Lamellae occur in a vertical series of two or more, and each lamella must have an overlying eluvial horizon. (An eluvial horizon is not required above the uppermost lamella if the soil is truncated.)

Lamellae may meet the requirements for either a cambic or an argillic horizon. A combination of two or more lamellae 15 cm or more thick is a cambic horizon if the texture class is very fine sand, loamy very fine sand, or finer. A combination of two or more lamellae meets the requirements for an argillic horizon if there is 15 cm or more cumulative thickness of lamellae that are 0.5 cm or more thick and that have a clay content of *either*:

1. 3 percent or more (absolute) higher than in the overlying eluvial horizon (e.g., 13 percent versus 10 percent) if any part of the eluvial horizon has less than 15 percent clay in the fine-earth fraction; *or*

2. 20 percent or more (relative) higher than in the overlying eluvial horizon (e.g., 24 percent versus 20 percent) if all parts of the eluvial horizon have more than 15 percent clay in the fine-earth fraction.

Linear Extensibility (LE)

Linear extensibility (LE) helps to predict the potential of a soil to shrink and swell. The LE of a soil layer is the product of the thickness, in cm, multiplied by the COLE of the layer in question. The LE of a soil is the sum of these products for all soil horizons. Linear extensibility is a criterion for most Vertic subgroups in this taxonomy and is calculated as summed products from the mineral soil surface to a depth of 100 cm or to a root-limiting layer (defined in chapter 17).

Lithologic Discontinuities

Lithologic discontinuities are significant changes in particle-size distribution or mineralogy that represent differences in lithology within a soil. A lithologic discontinuity can also denote an age difference. For information on using horizon designations for lithologic discontinuities, see the *Soil Survey Manual* (Soil Survey Division Staff, 1993) and chapter 18 of this document.

Not everyone agrees on the degree of change required for a lithologic discontinuity. No attempt is made to quantify lithologic discontinuities. The discussion below is meant to serve as a guideline.

Several lines of field evidence can be used to evaluate lithologic discontinuities. In addition to mineralogical and textural differences that may require laboratory studies, certain observations can be made in the field. These include but are not limited to the following:

1. Abrupt textural contacts.—An abrupt change in particle-size distribution, which is not solely a change in clay content resulting from pedogenesis, can often be observed.

2. Contrasting sand sizes.—Significant changes in sand size can be detected. For example, if material containing mostly medium sand or finer sand abruptly overlies material containing mostly coarse sand and very coarse sand, one can assume that there are two different materials. Although the materials may be of the same mineralogy, the contrasting sand sizes result from differences in energy at the time of deposition by water and/or wind.

3. Bedrock lithology vs. rock fragment lithology in the soil.—If a soil with rock fragments overlies a lithic contact, one would expect the rock fragments to have a lithology similar to that of the material below the lithic contact. If many of the rock fragments do not have the same lithology as the underlying bedrock, the soil is not derived completely from the underlying bedrock.

4. Stone lines.—The occurrence of a horizontal line of rock fragments in the vertical sequence of a soil indicates that the soil may have developed in more than one kind of parent material. The material above the stone line is most likely transported, and the material below may be of different origin.

5. **Inverse distribution of rock fragments.**—A lithologic discontinuity is often indicated by an erratic distribution of rock fragments. The percentage of rock fragments decreases with increasing depth. This line of evidence is useful in areas of soils that have relatively unweathered rock fragments.

6. **Rock fragment weathering rinds.**—Horizons containing rock fragments with no rinds that overlie horizons containing rocks with rinds suggest that the upper material is in part depositional and not related to the lower part in time and perhaps in lithology.

7. **Shape of rock fragments.**—A soil with horizons containing angular rock fragments overlying horizons containing well rounded rock fragments may indicate a discontinuity. This line of evidence represents different mechanisms of transport (colluvial vs. alluvial) or even different transport distances.

8. **Soil color.**—Abrupt changes in color that are not the result of pedogenic processes can be used as indicators of discontinuity.

9. **Micromorphological features.**—Marked differences in the size and shape of resistant minerals in one horizon and not in another are indicators of differences in materials.

Use of Laboratory Data

Discontinuities are not always readily apparent in the field. In these cases laboratory data are necessary. Even with laboratory data, detecting discontinuities may be difficult. The decision is a qualitative or perhaps a partly quantitative judgment. General concepts of lithology as a function of depth might include:

1. **Laboratory data—visual scan.**—The array of laboratory data is assessed in an attempt to determine if a field-designated discontinuity is corroborated and if any data show evidence of a discontinuity not observed in the field. One must sort changes in lithology from changes caused by pedogenic processes. In most cases the quantities of sand and coarser fractions are not altered significantly by soil-forming processes. Therefore, an abrupt change in sand size or sand mineralogy is a clue to lithologic change. Gross soil mineralogy and the resistant mineral suite are other clues.

2. **Data on a clay-free basis.**—A common manipulation in assessing lithologic change is computation of sand and silt separates on a carbonate-free, clay-free basis (percent fraction, e.g., fine sand and very fine sand, divided by percent sand plus silt, times 100). Clay distribution is subject to pedogenic change and may either mask inherited lithologic differences or produce differences that are not inherited from lithology. The numerical array computed on a clay-free basis can be inspected visually or plotted as a function of depth.

Another aid used to assess lithologic changes is computation of the ratios of one sand separate to another. The ratios can be computed and examined as a numerical array, or they can be plotted. The ratios work well if sufficient quantities of the two fractions are available. Low quantities magnify changes in ratios, especially if the denominator is low.

n Value

The *n* value (Pons and Zonneveld, 1965) characterizes the relation between the percentage of water in a soil under field conditions and its percentages of inorganic clay and humus. The *n* value is helpful in predicting whether a soil can be grazed by livestock or can support other loads and in predicting what degree of subsidence would occur after drainage.

For mineral soil materials that are not thixotropic, the *n* value can be calculated by the following formula:

$$n = (A - 0.2R)/(L + 3H)$$

In this formula, A is the percentage of water in the soil in field condition, calculated on a dry-soil basis; R is the percentage of silt plus sand; L is the percentage of clay; and H is the percentage of organic matter (percent organic carbon multiplied by 1.724).

Few data for calculations of the *n* value are available in the United States, but the critical *n* value of 0.7 can be approximated closely in the field by a simple test of squeezing a soil sample in the palm of a hand. If the soil flows between the fingers with difficulty, the *n* value is between 0.7 and 1.0 (slightly fluid manner of failure class); if the soil flows easily between the fingers, the *n* value is 1 or more (moderately fluid or very fluid manner of failure class); and if no soil material flows through the fingers during full compression, the sample has an *n* value less than 0.7 (nonfluid manner of failure class).

Petroferric Contact

A petroferric (Gr. *petra*, rock, and L. *ferrum*, iron; implying ironstone) contact is a boundary between soil and a continuous layer of indurated material in which iron is an important cement and organic matter is either absent or present only in traces. The indurated layer must be continuous within the limits of each pedon, but it may be fractured if the average lateral distance between fractures is 10 cm or more. The fact that this ironstone layer contains little or no organic matter distinguishes it from a placic horizon and an indurated spodic horizon (ortstein), both of which contain organic matter.

Several features can aid in making the distinction between a lithic contact and a petroferric contact. First, a petroferric contact is roughly horizontal. Second, the material directly below a petroferric contact contains a high amount of iron (normally 30 percent or more Fe_2O_3). Third, the ironstone sheets below a petroferric contact are thin; their thickness ranges from a few centimeters to very few meters. Sandstone, on the other hand, may be thin or very thick, may be level-bedded or tilted, and may contain only a small percentage of Fe_2O_3. In the Tropics, the ironstone is generally more or less vesicular.

Plinthite

Plinthite (Gr. *plinthos*, brick) is an iron-rich, humus-poor mixture of clay with quartz and other minerals. It commonly occurs as dark red redox concentrations that usually form platy, polygonal, or reticulate patterns. Plinthite changes irreversibly to an ironstone hardpan or to irregular aggregates on exposure to repeated wetting and drying, especially if it is also exposed to heat from the sun. The lower boundary of a zone in which plinthite occurs generally is diffuse or gradual, but it may be abrupt at a lithologic discontinuity.

Plinthite may occur as a constituent of a number of horizons, such as an epipedon, a cambic horizon, an argillic horizon, an oxic horizon, or a C horizon. It is one form of the material that has been called laterite. It normally forms in a horizon below the surface, but it may form at the surface in a seep area at the base of a slope.

From a genetic viewpoint, plinthite forms by segregation of iron. In many places iron probably has been added from other horizons or from the higher adjacent soils. Generally, plinthite forms in a horizon that is saturated with water for some time during the year. Initially, iron is normally segregated in the form of soft, more or less clayey, red or dark red redox concentrations. These concentrations are not considered plinthite unless there has been enough segregation of iron to permit their irreversible hardening on exposure to repeated wetting and drying.

Plinthite is firm or very firm when the soil moisture content is near field capacity and hard when the moisture content is below the wilting point. Plinthite occurs as discrete bodies larger than 2 mm that can be separated from the matrix. A moist aggregate of plinthite will withstand moderate rolling between thumb and forefinger and is less than strongly cemented. Moist or air-dried plinthite will not slake when submerged in water even with gentle agitation. Plinthite does not harden irreversibly as a result of a single cycle of drying and rewetting. After a single drying, it will remoisten and then can be dispersed in large part if one shakes it in water with a dispersing agent.

In a moist soil, plinthite is soft enough to be cut with a spade. After irreversible hardening, it is no longer considered plinthite but is called ironstone. Indurated ironstone materials can be broken or shattered with a spade but cannot be dispersed if one shakes them in water with a dispersing agent.

A small amount of plinthite in the soil does not form a continuous phase; that is, the individual redox concentrations or aggregates are not connected with each other. If a large amount of plinthite is present, it may form a continuous phase. Individual aggregates of plinthite in a continuous phase are interconnected, and the spacing of cracks or zones that roots can enter is 10 cm or more.

If a continuous layer becomes indurated, it is a massive ironstone layer that has irregular, somewhat tubular inclusions of yellowish, grayish, or white, clayey material. If the layer is exposed, these inclusions may be washed out, leaving an ironstone that has many coarse, tubular pores.

Much that has been called laterite is included in the meaning of plinthite. Doughy and concretionary laterite that has not hardened is an example. Hardened laterite, whether it is vesicular or pisolitic, is not included in the definition of plinthite.

Resistant Minerals

Several references are made to resistant minerals in this taxonomy. Obviously, the stability of a mineral in the soil is a partial function of the soil moisture regime. Where resistant minerals are referred to in the definitions of diagnostic horizons and of various taxa, a humid climate, past or present, is always assumed.

Resistant minerals are durable minerals in the 0.02 to 2.0 mm fraction. Examples are quartz, zircon, tourmaline, beryl, anatase, rutile, iron oxides and oxyhydroxides, 1:1 dioctahedral phyllosilicates (kandites), gibbsite, and hydroxy-aluminum interlayered 2:1 minerals (Burt and Soil Survey Staff, 2014).

Slickensides

Slickensides are polished and grooved surfaces and generally have dimensions exceeding 5 cm. They are produced when one soil mass slides past another. Some slickensides occur at the lower boundary of a slip surface where a mass of soil moves downward on a relatively steep slope. Slickensides result directly from the swelling of clay minerals and shear failure. They are very common in swelling clays that undergo marked changes in moisture content.

Spodic Materials

Spodic materials form in an illuvial horizon that normally underlies a histic, ochric, or umbric epipedon or an albic horizon. In most undisturbed areas, spodic materials underlie an albic horizon. They may occur within an umbric epipedon or an Ap horizon.

A horizon consisting of spodic materials normally has an optical density of oxalate extract (ODOE) value of 0.25 or more, and that value is commonly at least 2 times as high as the ODOE value in an overlying eluvial horizon. This increase in ODOE value indicates an accumulation of translocated organic materials in an illuvial horizon. Soils with spodic materials show evidence that organic materials and aluminum, with or without iron, have been moved from an eluvial horizon to an illuvial horizon.

Definition of Spodic Materials

Spodic materials are mineral soil materials that do not have all of the properties of an argillic or kandic horizon; are dominated by active amorphous materials that are illuvial and are composed of organic matter and aluminum, with or without iron; and have *both* of the following:

1. A pH value in water (1:1) of 5.9 or less and an organic-carbon content of 0.6 percent or more; *and*

2. *One or both* of the following:

a. An overlying albic horizon that extends horizontally through 50 percent or more of each pedon and, directly under the albic horizon, colors, moist (crushed and smoothed sample), as follows:

(1) Hue of 5YR or redder; *or*

(2) Hue of 7.5YR, color value of 5 or less, and chroma of 4 or less; *or*

(3) Hue of 10YR or neutral and a color value and chroma of 2 or less; *or*

(4) A color of 10YR 3/1; *or*

b. With or without an albic horizon and one of the colors listed above or hue of 7.5YR, color value, moist, of 5 or less, and chroma of 5 or 6 (crushed and smoothed sample), and *one or more* of the following morphological or chemical properties:

(1) Cementation by organic matter and aluminum, with or without iron, in 50 percent or more of each pedon and a very firm or firmer rupture-resistance class in the cemented part; *or*

(2) 10 percent or more cracked coatings on sand grains; *or*

(3) Al plus $^1/_2$ Fe percentages (by ammonium oxalate) totaling 0.50 or more, and half that amount or less in an overlying umbric (or subhorizon of an umbric) epipedon, ochric epipedon, or albic horizon; *or*

(4) An optical density of oxalate extract (ODOE) value of 0.25 or more, and a value half as high or lower in an overlying umbric (or subhorizon of an umbric) epipedon, ochric epipedon, or albic horizon.

Volcanic Glass

Volcanic glass is defined herein as optically isotropic translucent glass or pumice of any color. It includes glass, pumice, glass-coated crystalline minerals, glass aggregates, and glassy materials.

Volcanic glass is typically a dominant component in relatively unweathered tephra. Weathering and mineral transformation of volcanic glass can produce short-range-order minerals, such as allophane, imogolite, and ferrihydrite.

Volcanic glass content is the percent (by grain count) of glass, glass-coated mineral grains, glass aggregates, and glassy materials in the 0.02 to 2.0 mm fraction. Typically, the content is determined for one particle-size fraction (i.e., coarse silt, very fine sand, or fine sand) and used as an estimate of glass content in the 0.02 to 2.0 mm fraction.

Volcanic glass content is a criterion in classification of andic soil properties, subgroups with the formative element “vitr(i),” families with “ashy” substitutes for particle-size class, and the glassy mineralogy class.

Weatherable Minerals

Several references are made to weatherable minerals in this taxonomy. Obviously, the stability (i.e., ability to remain unaltered) of a mineral in a soil is a partial function of the soil moisture regime. Where weatherable minerals are referred to in the definitions of diagnostic horizons and of various taxa in this taxonomy, a humid climate, either present or past, is always assumed. Examples of the minerals that are included in the meaning of weatherable minerals are all 2:1 phyllosilicates, chlorite, sepiolite, palygorskite, allophane, 1:1 trioctahedral phyllosilicates (serpentines), feldspars, feldspathoids, ferromagnesian minerals, volcanic glass, zeolites, dolomite, and apatite in the 0.02 to 2.0 mm fraction.

Obviously, this definition of the term “weatherable minerals” is restrictive. The intent is to include, in the definitions of diagnostic horizons and various taxa, only those weatherable minerals that are unstable in a humid climate compared to other minerals, such as quartz and 1:1 lattice clays, but that are more resistant to weathering than calcite. Calcite, carbonate aggregates, anhydrite, gypsum, and halite are not considered weatherable minerals because they are mobile in the soil. Mobile minerals appear to be recharged in some otherwise strongly weathered soils.

Characteristics Diagnostic for Organic Soils

Following is a description of the characteristics that are used only with organic soils.

Kinds of Organic Soil Materials

Three different kinds of organic soil materials are distinguished in this taxonomy, based on the degree of decomposition of the plant materials from which the organic materials are derived. The three kinds are (1) fibric, (2) hemic, and (3) sapric. Because of the importance of fiber content in the definitions of these materials, fibers are defined before the kinds of organic soil materials.

Fibers

Fibers are pieces of plant tissue in organic soil materials (excluding live roots) that:

1. Are large enough to be retained on a 100-mesh sieve (openings 0.15 mm across) when the materials are screened; *and*

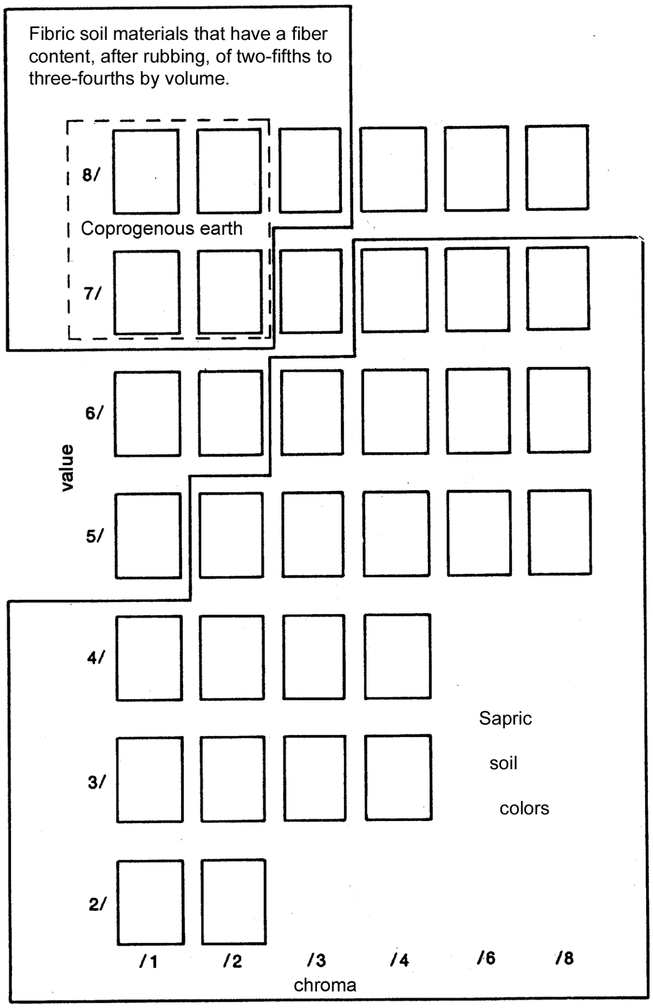

Figure 2.—Value and chroma of pyrophosphate solution of fibric and sapric soil materials.

2. Show evidence of the cellular structure of the plants from which they are derived; *and*

3. Either are 20 mm or less in their smallest dimension or are decomposed enough to be crushed and shredded with the fingers.

Pieces of wood that are larger than 20 mm in cross section and are so undecomposed that they cannot be crushed and shredded with the fingers, such as large branches, logs, and stumps, are not considered fibers but are considered wood fragments (comparable to rock fragments in mineral soils). Wood fragments may be in the soil or on the soil surface.

Fibric Soil Materials

Fibric soil materials are organic soil materials that *either*:

1. Contain three-fourths or more (by volume) fibers after rubbing, excluding wood fragments (defined above); *or*

2. Contain two-fifths or more (by volume) fibers after rubbing, excluding coarse fragments, and yield color values and chromas of 7/1, 7/2, 8/1, 8/2, or 8/3 (fig. 2) on white chromatographic or filter paper that is inserted into a paste made of the soil materials in a saturated sodium-pyrophosphate solution.

Hemic Soil Materials

Hemic (Gr. *hemi*, half; implying intermediate decomposition) soil materials are intermediate in their degree of decomposition between the less decomposed fibric and more decomposed sapric materials. Their morphological features give intermediate values for fiber content, bulk density, and water content. Hemic soil materials are partly altered both physically and biochemically.

Sapric Soil Materials

Sapric (Gr. *sapros*, rotten) soil materials are the most highly decomposed of the three kinds of organic soil materials. They have the smallest amount of plant fiber, the highest bulk density, and the lowest water content on a dry-weight basis at saturation. Sapric soil materials are commonly very dark gray to black. They are relatively stable; i.e., they change very little physically and chemically with time in comparison to other organic soil materials.

Sapric materials have the following characteristics:

1. The fiber content, after rubbing, is less than one-sixth (by volume), excluding wood fragments (defined above); *and*

2. The color of the sodium-pyrophosphate extract on white chromatographic or filter paper is below or to the right of a line drawn to exclude blocks 5/1, 6/2, and 7/3 (fig. 2). If few or no fibers can be detected and the color of the pyrophosphate extract is to the left of or above this line, the possibility that the material is limnic must be considered.

Humilluvic Material

Humilluvic material, i.e., illuvial humus, accumulates in the lower parts of some organic soils that are acid and have been drained and cultivated. The humilluvic material has a C^{14} age that is not older than the overlying organic materials. It has very high solubility in sodium pyrophosphate and rewets very slowly after drying. Most commonly, it accumulates near a contact with a sandy mineral horizon.

To be recognized as a differentia in classification, the humilluvic material must constitute one-half or more (by volume) of a layer 2 cm or more thick.

Kinds of Limnic Materials

The presence or absence of limnic deposits is taken into account in the higher categories of Histosols but not Histels.

The nature of such deposits is considered in the lower categories of Histosols. Limnic materials include both organic and inorganic materials that were either (1) deposited in water by precipitation or through the action of aquatic organisms, such as algae or diatoms, or (2) derived from underwater and floating aquatic plants and subsequently modified by aquatic animals. They include coprogenous earth (sedimentary peat), diatomaceous earth, and marl.

Coprogenous Earth

A layer of coprogenous earth (sedimentary peat) is a limnic layer that:

1. Contains many fecal pellets with diameters between a few hundredths and a few tenths of a millimeter; *and*

2. Has a color value of 4 or less, moist; *and*

3. Either forms a slightly viscous water suspension and is nonplastic or slightly plastic but not sticky, or shrinks upon drying, forming clods that are difficult to rewet and often tend to crack along horizontal planes; *and*

4. Either yields a saturated sodium-pyrophosphate extract on white chromatographic or filter paper that has a color value of 7 or more and chroma of 2 or less (fig. 2) or has a cation-exchange capacity of less than 240 cmol(+) per kg organic matter (measured by loss on ignition), or both.

Diatomaceous Earth

A layer of diatomaceous earth is a limnic layer that:

1. If not previously dried, has a matrix color value of 3, 4, or 5, which changes irreversibly on drying as a result of the irreversible shrinkage of organic-matter coatings on diatoms (identifiable by microscopic, 440 X, examination of dry samples); *and*

2. Either yields a saturated sodium-pyrophosphate extract on white chromatographic or filter paper that has a color value of 8 or more and chroma of 2 or less or has a cation-exchange capacity of less than 240 cmol(+) per kg organic matter (measured by loss on ignition), or both.

Marl

A layer of marl is a limnic layer that:

1. Has a color value of 5 or more, moist; *and*

2. Reacts with dilute HCl to evolve CO_2.

The color of marl usually does not change irreversibly on drying because a layer of marl contains too little organic matter, even before it has been shrunk by drying, to coat the carbonate particles.

Thickness of Organic Soil Materials (Control Section of Histosols and Histels)

The thickness of organic materials over limnic materials, mineral materials, water, or permafrost is used to define Histosols and Histels.

For practical reasons, an arbitrary control section has been established for the classification of Histosols and Histels. Depending on the kinds of soil material in the surface layers, the control section has a thickness of either 130 cm or 160 cm from the soil surface if there is no densic, lithic, or paralithic contact, thick layer of water, or permafrost within the respective limit. The thicker control section is used if the surface layers to a depth of 60 cm either contain three-fourths or more fibers derived from *Sphagnum*, *Hypnum*, or other mosses or have a bulk density of less than 0.1 g/cm^3. Layers of water, which may be between a few centimeters and many meters thick in these soils, are considered to be the lower boundary of the control section only if the water extends below a depth of 130 or 160 cm, respectively. A densic, lithic, or paralithic contact, if shallower than 130 or 160 cm, constitutes the lower boundary of the control section. In some soils the lower boundary is 25 cm below the upper limit of permafrost. An unconsolidated mineral substratum shallower than those limits does not change the lower boundary of the control section.

The control section of Histosols and Histels is divided somewhat arbitrarily into three tiers—surface, subsurface, and bottom tiers.

Surface Tier

The surface tier of a Histosol or Histel extends from the soil surface to a depth of 60 cm if either (1) the materials within that depth are fibric and three-fourths or more of the fiber volume is derived from *Sphagnum* or other mosses or (2) the materials have a bulk density of less than 0.1 g/cm^3. Otherwise, the surface tier extends from the soil surface to a depth of 30 cm.

Some organic soils have a mineral surface layer less than 40 cm thick as a result of flooding, volcanic eruptions, additions of mineral materials to increase soil strength or reduce the hazard of frost, or other causes. If such a mineral layer is less than 30 cm thick, it constitutes the upper part of the surface tier; if it is 30 to 40 cm thick, it constitutes the whole surface tier and part of the subsurface tier.

Subsurface Tier

The subsurface tier is normally 60 cm thick. If the control section ends at a shallower depth (at a densic, lithic, or paralithic contact or a water layer or in permafrost), however, the subsurface tier extends from the lower boundary of the surface tier to the lower boundary of the control section. It includes any unconsolidated mineral layers that may be present within those depths.

Bottom Tier

The bottom tier is 40 cm thick unless the control section has its lower boundary at a shallower depth (at a densic, lithic, or paralithic contact or a water layer or in permafrost).

Thus, if the organic materials are thick, there are two possible thicknesses of the control section, depending on the presence or absence and the thickness of a surface mantle of fibric moss or other organic material that has a low bulk density (less than 0.1 g/cm^3). If the fibric moss extends to a depth of 60 cm and is the dominant material within this depth (three-fourths or more of the volume), the control section is 160 cm thick. If the fibric moss is thin or absent, the control section extends to a depth of 130 cm.

Horizons and Characteristics Diagnostic for Both Mineral and Organic Soils

Following are descriptions of the horizons and characteristics that are diagnostic for both mineral and organic soils.

Aquic Conditions

Soils with aquic (L. *aqua*, water) conditions are those that currently undergo continuous or periodic saturation and reduction. The presence of these conditions is indicated by redoximorphic features, except in Histosols and Histels, and can be verified by measuring saturation and reduction, except in artificially drained soils. Artificial drainage is defined here as the removal of free water from soils having aquic conditions by surface mounding, ditches, or subsurface tiles or the prevention of surface or ground water from reaching the soils by dams, levees, surface pumps, or other means. In these soils water table levels and/or their duration are changed significantly in connection with specific types of land use. Upon removal of the drainage practices, aquic conditions would return. In the keys, artificially drained soils are included with soils that have aquic conditions.

Elements of aquic conditions are as follows:

1. Saturation is characterized by zero or positive pressure in the soil water and can generally be determined by observing free water in an unlined auger hole. Problems may arise, however, in clayey soils with peds, where an unlined auger hole may fill with water flowing along faces of peds while the soil matrix is and remains unsaturated (bypass flow). Such free water may incorrectly suggest the presence of a water table, while the actual water table occurs at greater depth. Use of well-sealed piezometers or tensiometers is therefore recommended for measuring saturation. Problems may still occur, however, if water runs into piezometer slits near the bottom of the piezometer hole or if tensiometers with slowly reacting manometers are used. The first problem can be overcome by using piezometers with smaller slits and the second by using transducer tensiometry, which reacts faster than manometers. Soils are considered wet if they have pressure heads greater than -1 kPa. Only macropores, such as cracks between peds or channels, are then filled with air, while the soil matrix is usually still saturated. Obviously, exact measurements of the wet state can be obtained only with tensiometers. For operational purposes, the use of piezometers is recommended as a standard method.

The duration of saturation required for creating aquic conditions varies, depending on the soil environment, and is not specified.

Three types of saturation are defined:

a. *Endosaturation.*—The soil is saturated with water in all layers from the upper boundary of saturation to a depth of 200 cm or more from the mineral soil surface.

b. *Episaturation.*—The soil is saturated with water in one or more layers within 200 cm of the mineral soil surface and also has one or more unsaturated layers, with an upper boundary above a depth of 200 cm, below the saturated layer. The zone of saturation, i.e., the water table, is perched on top of a relatively impermeable layer.

c. *Anthric saturation.*—This term refers to a special kind of aquic condition that occurs in soils that are cultivated and irrigated (flood irrigation). Soils with anthraquic conditions must meet the requirements for aquic conditions and in addition have *both* of the following:

(1) A tilled surface layer and a directly underlying slowly permeable layer that has, for 3 months or more in normal years, *both*:

(a) Saturation and reduction; *and*

(b) Chroma of 2 or less in the matrix; *and*

(2) A subsurface horizon with *one or more* of the following:

(a) Redox depletions with a color value of 4 or more, moist, and chroma of 2 or less in macropores; *or*

(b) Redox concentrations of iron and/or manganese; *or*

(c) 2 times or more the amount of iron (extractable by dithionite-citrate) than is contained in the tilled surface layer.

2. The degree of reduction in a soil can be characterized by the direct measurement of redox potentials. Direct measurements should take into account chemical equilibria as expressed by stability diagrams in standard soil textbooks. Reduction and oxidation processes are also a function of soil pH. Obtaining accurate measurements of the degree of reduction in a soil is difficult. In the context of this taxonomy, however, only a degree of reduction that results in reduced iron is considered, because it produces the visible redoximorphic

features that are identified in the keys. A simple field test is available to determine if reduced iron ions are present. A freshly broken surface of a field-wet soil sample is treated with alpha,alpha-dipyridyl in neutral, 1N ammonium acetate solution. The appearance of a strong red color on the freshly broken surface indicates the presence of reduced iron ions (i.e., Fe^{2+}). A positive reaction to the alpha,alpha-dipyridyl field test for ferrous iron (Childs, 1981) may be used to confirm the existence of reducing conditions and is especially useful in situations where, despite saturation, normal morphological indicators of such conditions are either absent or obscured (as by the dark colors characteristic of melanic great groups). A negative reaction, however, does not imply that reducing conditions are always absent. It may only mean that the level of free iron in the soil is below the sensitivity limit of the test or that the soil is in an oxidized phase at the time of testing. For soils with very low levels of iron, the use of a field test such as Indicator of Reduction in Soils (IRIS) tubes painted with ferric iron may be warranted in order to document reducing conditions. Use of alpha,alpha-dipyridyl in a 10 percent solution of aceticacid is not recommended because the acid is likely to change soil conditions, for example, by dissolving $CaCO_3$.

The duration of reduction required for creating aquic conditions is not specified.

3. Redoximorphic features associated with wetness result from alternating periods of reduction and oxidation of iron and manganese compounds in the soil. Reduction occurs during saturation with water, and oxidation occurs when the soil is not saturated. The reduced iron and manganese ions are mobile and may be transported by water as it moves through the soil. Certain redox patterns occur as a function of the patterns in which the ion-carrying water moves through the soil and as a function of the location of aerated zones in the soil. Redox patterns are also affected by the fact that manganese is reduced more rapidly than iron, while iron oxidizes more rapidly upon aeration. Characteristic color patterns are created by these processes. The reduced iron and manganese ions may be removed from a soil if vertical or lateral fluxes of water occur, in which case there is no iron or manganese precipitation in that soil. Wherever the iron and manganese are oxidized and precipitated, they form either soft masses or hard concretions or nodules. Movement of iron and manganese as a result of redox processes in a soil may result in redoximorphic features that are defined as follows:

a. *Redox concentrations.*—These are zones of apparent accumulation of Fe-Mn oxides, including:

(1) Nodules and concretions, which are cemented bodies that can be removed from the soil intact. Concretions are distinguished from nodules on the basis of internal organization. A concretion typically has concentric layers that are visible to the naked eye. Nodules do not have visible organized internal structure. Boundaries commonly are diffuse if formed *in situ* and sharp after pedoturbation. Sharp boundaries may be relict features in some soils; *and*

(2) Masses, which are noncemented concentrations of substances within the soil matrix; *and*

(3) Pore linings, i.e., zones of accumulation along pores that may be either coatings on pore surfaces or impregnations from the matrix adjacent to the pores.

b. *Redox depletions.*—These are zones of low chroma (chromas less than those in the matrix) where either Fe-Mn oxides alone or both Fe-Mn oxides and clay have been stripped out, including:

(1) Iron depletions, i.e., zones that contain low amounts of Fe and Mn oxides but have a clay content similar to that of the adjacent matrix (often referred to as albans or neoalbans); *and*

(2) Clay depletions, i.e., zones that contain low amounts of Fe, Mn, and clay (often referred to as silt coatings or skeletans).

c. *Reduced matrix.*—This is a soil matrix that has low chroma *in situ* but undergoes a change in hue or chroma within 30 minutes after the soil material has been exposed to air.

d. In soils that have no visible redoximorphic features, a reaction to an alpha,alpha-dipyridyl solution satisfies the requirement for redoximorphic features.

Field experience indicates that it is not possible to define a specific set of redoximorphic features that is uniquely characteristic of all of the taxa in one particular category. Therefore, color patterns that are unique to specific taxa are referenced in the keys.

Anthraquic conditions are a variant of episaturation and are associated with controlled flooding (for such crops as wetland rice and cranberries), which causes reduction processes in the saturated, puddled surface soil and oxidation of reduced and mobilized iron and manganese in the unsaturated subsoil.

Cryoturbation

Cryoturbation (frost churning) is the mixing of the soil matrix within the pedon that results in irregular or broken horizons, involutions, accumulation of organic matter on the permafrost table, oriented rock fragments, and silt caps on rock fragments.

Densic Contact

A densic (L. *densus*, thick) contact is a contact between soil and densic materials (defined below). It has no cracks, or the spacing of cracks that roots can enter is 10 cm or more.

Densic Materials

Densic materials are relatively unaltered materials (do not meet the requirements for any other named diagnostic horizons or any other diagnostic soil characteristic) that have a noncemented rupture-resistance class. The bulk density or the organization is such that roots cannot enter, except in cracks. These are mostly earthy materials, such as till, volcanic mudflows, and some mechanically compacted materials, for example, mine spoils. Some noncemented rocks can be densic materials if they are dense or resistant enough to keep roots from entering, except in cracks.

Densic materials are noncemented and thus differ from paralithic materials and the material below a lithic contact, both of which are cemented.

Densic materials have, at their upper boundary, a densic contact if they have no cracks or if the spacing of cracks that roots can enter is 10 cm or more. These materials can be used to differentiate soil series if the materials are within the series control section.

Gelic Materials

Gelic materials are mineral or organic soil materials that show evidence of cryoturbation (frost churning) and/or ice segregation in the active layer (seasonal thaw layer) and/or the upper part of the permafrost. Cryoturbation is manifested by irregular and broken horizons, involutions, accumulation of organic matter on top of and within the permafrost, oriented rock fragments, and silt-enriched layers. The characteristic structures associated with gelic materials include platy, blocky, or granular macrostructures; the structural results of sorting; and orbiculic, conglomeric, banded, or vesicular microfabrics. Ice segregation is manifested by ice lenses, vein ice, segregated ice crystals, and ice wedges. Cryopedogenic processes that lead to gelic materials are driven by the physical volume change of water to ice, moisture migration along a thermal gradient in the frozen system, or thermal contraction of the frozen material by continued rapid cooling.

Glacic Layer

A glacic layer is massive ice or ground ice in the form of ice lenses or wedges. The layer is 30 cm or more thick and contains 75 percent or more visible ice.

Lithic Contact

A lithic contact is the boundary between soil and a coherent underlying material. Except in Ruptic-Lithic subgroups, the underlying material must be virtually continuous within the limits of a pedon. Cracks that can be penetrated by roots are few, and their horizontal spacing is 10 cm or more. The underlying material must be sufficiently coherent when moist to make hand-digging with a spade impractical, although the material may be chipped or scraped with a spade. The material below a lithic contact must be in a strongly cemented or more cemented rupture-resistance class. Commonly, the material is indurated. The underlying material considered here does not include diagnostic soil horizons, such as a duripan or a petrocalcic horizon.

A lithic contact is diagnostic at the subgroup level if it is within 125 cm of the mineral soil surface in Oxisols and within 50 cm of the mineral soil surface in all other mineral soils. In Gelisols composed mainly of organic soil materials, the lithic contact is diagnostic at the subgroup level if it is within 50 cm of the soil surface in Folistels or within 100 cm of the soil surface in Fibristels, Hemistels, and Sapristels. In Histosols the lithic contact must be at the lower boundary of the control section to be recognized at the subgroup level.

Paralithic Contact

A paralithic (lithic-like) contact is a contact between soil and paralithic materials (defined below) where the paralithic materials have no cracks or the spacing of cracks that roots can enter is 10 cm or more.

Paralithic Materials

Paralithic materials are relatively unaltered materials (do not meet the requirements for any other named diagnostic horizons or any other diagnostic soil characteristic) that have an extremely weakly cemented to moderately cemented rupture-resistance class. Cementation, bulk density, and the organization are such that roots cannot enter, except in cracks. Paralithic materials have, at their upper boundary, a paralithic contact if they have no cracks or if the spacing of cracks that roots can enter is 10 cm or more. Commonly, these materials are partially weathered bedrock or weakly consolidated bedrock, such as sandstone, siltstone, or shale. Paralithic materials can be used to differentiate soil series if the materials are within the series control section. Fragments of paralithic materials 2.0 mm or more in diameter are referred to as pararock fragments.

Permafrost

Permafrost is defined as a thermal condition in which a material (including soil material) remains below 0 ^{o}C for 2 or more years in succession. Those gelic materials having permafrost contain the unfrozen soil solution that drives cryopedogenic processes. Permafrost may be impregnated by ice or, in the case of insufficient interstitial water, may be dry. The frozen layer has a variety of ice lenses, vein ice, segregated ice crystals, and ice wedges. The permafrost table is in dynamic equilibrium with the environment.

Soil Moisture Regimes

The term “soil moisture regime” refers to the presence or absence either of ground water or of water held at a tension of less than 1500 kPa in the soil or in specific horizons during periods of the year. Water held at a tension of 1500 kPa or more is not available to keep most mesophytic plants alive. The availability of water is also affected by dissolved salts. If a soil is saturated with water that is too salty to be available to most plants, it is considered salty rather than dry. Consequently, a horizon is considered dry when the moisture tension is 1500 kPa or more and is considered moist if water is held at a tension of less than 1500 kPa but more than zero. A soil may be continuously moist in some or all horizons either throughout the year or for some part of the year. It may be either moist in winter and dry in summer or the reverse. In the Northern Hemisphere, summer refers to June, July, and August and winter refers to December, January, and February.

Normal Years

In the discussions that follow and throughout the keys, the term "normal years" is used. A normal year is defined as a year that has:

1. Annual precipitation that is plus or minus one standard deviation of the long-term (30 years or more) mean annual precipitation; *and*

2. Mean monthly precipitation that is plus or minus one standard deviation of the long-term monthly precipitation for 8 of the 12 months.

For the most part, normal years can be calculated from the mean annual precipitation; however, when catastrophic events occur during a year, the standard deviations of the monthly means should also be calculated. The term "normal years" replaces the terms "most years" and "6 out of 10 years," which were used in the previous edition of *Soil Taxonomy* (Soil Survey Staff, 1975). When precipitation data are evaluated to determine if the criterion for the presence of aquic conditions, or number of days that the moisture control section is moist, or number of days that some part of the soil is saturated has been met, it is permissible to include data from periods with below normal rainfall. Similarly, when precipitation data are evaluated to determine if the criterion for the number of days that the moisture control section is dry has been met, it is permissible to include data from periods with above normal rainfall. It is assumed that if the criteria are met during these periods, they will also be met during normal years.

Soil Moisture Control Section

The intent in defining the soil moisture control section is to facilitate estimation of soil moisture regimes from climatic data. The upper boundary of this control section is the depth to which a dry (tension of more than 1500 kPa, but not air-dry) soil will be moistened by 2.5 cm of water within 24 hours. The lower boundary is the depth to which a dry soil will be moistened by 7.5 cm of water within 48 hours. These depths do not include the depth of moistening along any cracks or animal burrows that are open to the surface.

If 7.5 cm of water moistens the soil to a densic, lithic, paralithic, or petroferric contact or to a petrocalcic or petrogypsic horizon or a duripan, the contact or the upper boundary of the cemented horizon constitutes the lower boundary of the soil moisture control section. If a soil is moistened to one of these contacts or horizons by 2.5 cm of water, the soil moisture control section is the boundary of the contact itself. The control section of such a soil is considered moist if the contact or upper boundary of the cemented horizon has a thin film of water. If that upper boundary is dry, the control section is considered dry.

The moisture control section of a soil extends approximately (1) from 10 to 30 cm below the soil surface if the particle-size class of the soil is fine-loamy, coarse-silty, fine-silty, or clayey; (2) from 20 to 60 cm if the particle-size class is coarse-loamy; and (3) from 30 to 90 cm if the particle-size class is sandy. If the soil contains rock and pararock fragments that do not absorb and release water, the limits of the moisture control section are deeper. The limits of the soil moisture control section are affected not only by the particle-size class but also by differences in soil structure or pore-size distribution or by other factors that influence the movement and retention of water in the soil.

Classes of Soil Moisture Regimes

The soil moisture regimes are defined in terms of the level of ground water and in terms of the seasonal presence or absence of water held at a tension of less than 1500 kPa in the moisture control section. It is assumed in the definitions that the soil supports whatever vegetation it is capable of supporting, i.e., crops, grass, or native vegetation, and that the amount of stored moisture is not being increased by irrigation or fallowing. These cultural practices affect the soil moisture conditions as long as they are continued.

Aquic soil moisture regime.—The aquic (L. *aqua*, water) soil moisture regime is a reducing regime in a soil that is virtually free of dissolved oxygen because it is saturated by water. Some soils are saturated with water at times while dissolved oxygen is present, either because the water is moving or because the environment is unfavorable for micro-organisms (e.g., if the temperature is less than 1 ^{o}C); such a regime is not considered aquic.

It is not known how long a soil must be saturated before it is said to have an aquic soil moisture regime, but the duration must be at least a few days, because it is implicit in the concept that dissolved oxygen is virtually absent. Because dissolved oxygen is removed from ground water by respiration of micro-organisms, roots, and soil fauna, it is also implicit in the concept that the soil temperature is above biologic zero for some time while the soil is saturated. Biologic zero is defined as 5 ^{o}C in this taxonomy. In some of the very cold regions of the world, however, biological activity occurs at temperatures below 5 ^{o}C.

Very commonly, the level of ground water fluctuates with the seasons; it is highest in the rainy season or in fall, winter, or spring if cold weather virtually stops evapotranspiration. There are soils, however, in which the ground water is always at or very close to the surface. Examples are soils in tidal marshes or in closed, landlocked depressions fed by perennial streams. Such soils are considered to have a peraquic soil moisture regime.

Aridic and torric (L. *aridus*, dry, and L. *torridus*, hot and dry) soil moisture regimes.—These terms are used for the same moisture regime but in different categories of the taxonomy.

In the aridic (torric) soil moisture regime, the moisture control section is, in normal years:

1. Dry in all parts for more than half of the cumulative days per year when the soil temperature at a depth of 50 cm below the soil surface is above 5 °C; *and*

2. Moist in some or all parts for less than 90 consecutive days when the soil temperature at a depth of 50 cm below the soil surface is above 8 °C.

Soils that have an aridic (torric) soil moisture regime normally occur in areas of arid climates. A few are in areas of semiarid climates and either have physical properties that keep them dry, such as a crusty surface that virtually precludes the infiltration of water, or are on steep slopes where runoff is high. There is little or no leaching in this soil moisture regime, and soluble salts accumulate in the soils if there is a source.

The limits set for soil temperature exclude from these soil moisture regimes soils in the very cold and dry polar regions and in areas at high elevations. Such soils are considered to have anhydrous conditions (defined earlier).

Udic soil moisture regime.—The udic (L. *udus*, humid) soil moisture regime is one in which the soil moisture control section is not dry in any part for as long as 90 cumulative days in normal years. If the mean annual soil temperature is lower than 22 °C and if the mean winter and mean summer soil temperatures at a depth of 50 cm below the soil surface differ by 6 °C or more, the soil moisture control section, in normal years, is dry in all parts for less than 45 consecutive days in the 4 months following the summer solstice. In addition, the udic soil moisture regime requires, except for short periods, a three-phase system, solid-liquid-gas, in part or all of the soil moisture control section when the soil temperature is above 5 °C.

The udic soil moisture regime is common to the soils of humid climates that have well distributed rainfall; have enough rain in summer so that the amount of stored moisture plus rainfall is approximately equal to, or exceeds, the amount of evapotranspiration; or have adequate winter rains to recharge the soils and cool, foggy summers, as in coastal areas. Water moves downward through the soils at some time in normal years.

In climates where precipitation exceeds evapotranspiration in all months of normal years, the moisture tension rarely reaches 100 kPa in the soil moisture control section, although there are occasional brief periods when some stored moisture is used. The water moves through the soil in all months when it is not frozen. Such an extremely wet soil moisture regime is called perudic (L. *per*, throughout in time, and L. *udus*, humid). In the names of most taxa, the formative element “ud” is used to indicate either a udic or a perudic regime; the formative element “per” is used in selected taxa.

Ustic soil moisture regime.—The ustic (L. *ustus*, burnt; implying dryness) soil moisture regime is intermediate between the aridic regime and the udic regime. Its concept is one of moisture that is limited but is present at a time when conditions are suitable for plant growth. The concept of the ustic soil moisture regime is not applied to soils that have permafrost (defined above).

If the mean annual soil temperature is 22 °C or higher or if the mean summer and winter soil temperatures differ by less than 6 °C at a depth of 50 cm below the soil surface, the soil moisture control section in areas of the ustic soil moisture regime is dry in some or all parts for 90 or more cumulative days in normal years. It is moist, however, in some part either for more than 180 cumulative days per year or for 90 or more consecutive days.

If the mean annual soil temperature is lower than 22 °C and if the mean summer and winter soil temperatures differ by 6 °C or more at a depth of 50 cm below the soil surface, the soil moisture control section in areas of the ustic soil moisture regime is dry in some or all parts for 90 or more cumulative days in normal years, but it is not dry in all parts for more than half of the cumulative days when the soil temperature at a depth of 50 cm is higher than 5 °C. If in normal years the moisture control section is moist in all parts for 45 or more consecutive days in the 4 months following the winter solstice, the moisture control section is dry in all parts for less than 45 consecutive days in the 4 months following the summer solstice.

In tropical and subtropical regions that have a monsoon climate with either one or two dry seasons, summer and winter seasons have little meaning. In those regions the soil moisture regime is ustic if there is at least one rainy season of 3 months or more. In temperate regions of subhumid or semiarid climates, the rainy seasons are usually spring and summer or spring and fall, but never winter. Native plants are mostly annuals or plants that have a dormant period while the soil is dry.

Xeric soil moisture regime.—The xeric (Gr. *xeros*, dry) soil moisture regime is the typical moisture regime in areas of Mediterranean climates, where winters are moist and cool and summers are warm and dry. The moisture, which falls during the winter, when potential evapotranspiration is at a minimum, is particularly effective for leaching. In areas of a xeric soil moisture regime, the soil moisture control section, in normal years, is dry in all parts for 45 or more consecutive days in the 4 months following the summer solstice and moist in all parts for 45 or more consecutive days in the 4 months following the winter solstice. Also, in normal years, the moisture control section is moist in some part for more than half of the cumulative days per year when the soil temperature at a depth of 50 cm below the soil surface is higher than 5 °C or for 90 or more consecutive days when the soil temperature at a depth of 50 cm is higher than 8 °C. The mean annual soil temperature is lower than 22 °C, and the mean summer and mean winter soil temperatures differ by 6 °C or more either at a depth of 50 cm below the soil surface or at a densic, lithic, or paralithic contact if shallower.

Soil Temperature Regimes

Classes of Soil Temperature Regimes

Following is a description of the soil temperature regimes used in defining classes at various categorical levels in this taxonomy.

Gelic (L. *gelare*, to freeze).— Soils in this temperature regime have a mean annual soil temperature at or below 0 °C (in Gelic suborders and Gelic great groups) or 1 °C or lower (in Gelisols) either at a depth of 50 cm below the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower.

Cryic (Gr. *kryos*, coldness; indicating very cold soils).—Soils in this temperature regime have a mean annual temperature between 0 and 8 °C but do not have permafrost.

1. In mineral soils the mean summer soil temperature (June, July, and August in the Northern Hemisphere and December, January, and February in the Southern Hemisphere) either at a depth of 50 cm below the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower, is as follows:

    a. If the soil is not saturated with water during some part of the summer and

        (1) If there is no O horizon: between 0 and 15 °C; *or*

        (2) If there is an O horizon: between 0 and 8 °C; *or*

    b. If the soil is saturated with water during some part of the summer and

        (1) If there is no O horizon: between 0 and 13 °C; *or*

        (2) If there is an O horizon or a histic epipedon: between 0 and 6 °C.

2. In organic soils the mean annual soil temperature is between 0 and 6 °C.

Cryic soils that have an aquic soil moisture regime commonly are churned by frost.

Isofrigid soils can also have a cryic soil temperature regime. A few with organic materials in the upper part are exceptions.

The concepts of the soil temperature regimes described below are used in defining classes of soils in the lower categories of soil taxonomy (i.e., family and soil series).

Frigid.—A soil with a frigid soil temperature regime is warmer in summer than a soil with a cryic regime, but its mean annual temperature is between 0 and 8 °C and the difference between mean summer (June, July, and August) and mean winter (December, January, and February) soil temperatures is 6 °C or more either at a depth of 50 cm below the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower.

Mesic.—The mean annual soil temperature is 8 °C or higher but lower than 15 °C, and the difference between mean summer and mean winter soil temperatures is 6 °C or more either at a depth of 50 cm below the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower.

Thermic.—The mean annual soil temperature is 15 °C or higher but lower than 22 °C, and the difference between mean summer and mean winter soil temperatures is 6 °C or more either at a depth of 50 cm below the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower.

Hyperthermic.—The mean annual soil temperature is 22 °C or higher, and the difference between mean summer and mean winter soil temperatures is 6 °C or more either at a depth of 50 cm below the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower.

If the name of a soil temperature regime has the prefix *iso*, the mean summer and mean winter soil temperatures differ by less than 6 °C at a depth of 50 cm or at a densic, lithic, or paralithic contact, whichever is shallower.

Isofrigid.—The mean annual soil temperature is lower than 8 °C.

Isomesic.—The mean annual soil temperature is 8 °C or higher but lower than 15 °C.

Isothermic.—The mean annual soil temperature is 15 °C or higher but lower than 22 °C.

Isohyperthermic.—The mean annual soil temperature is 22 °C or higher.

Sulfidic Materials

Sulfidic materials contain oxidizable sulfur compounds (elemental S or most commonly sulfide minerals, such as pyrite or iron monosulfides). They are mineral or organic soil materials that have a pH value of more than 3.5 and that become significantly more acid when oxidized. Sulfidic materials accumulate as a soil or sediment that is permanently saturated, generally with brackish water. The sulfates in the water are biologically reduced to sulfides as the materials accumulate. Sulfidic materials most commonly accumulate in coastal marshes near the mouth of rivers that carry noncalcareous sediments, but they may occur in freshwater marshes if there is sulfur in the water. Upland sulfidic materials may have accumulated in a similar manner in the geologic past.

If a soil containing sulfidic materials is drained or if sulfidic materials are otherwise exposed to aerobic conditions, the sulfides oxidize and form sulfuric acid. The pH value, which normally is near neutrality before drainage or exposure, may drop below 3. The acid may induce the formation of iron and aluminum sulfates. The iron hydroxysulfate mineral jarosite may segregate, forming the yellow redoximorphic concentrations that commonly characterize a sulfuric horizon.

The transition from sulfidic materials to a sulfuric horizon normally requires only a few months and may occur within a few weeks. A sample of sulfidic materials, if air-dried slowly in shade for about 2 months with occasional remoistening, becomes extremely acid.

Required Characteristics

Sulfidic materials have *one or both* of the following:

1. A pH value (1:1 in water) of more than 3.5, and, when the materials are incubated at room temperature as a layer 1 cm thick under moist aerobic conditions (repeatedly moistened and dried on a weekly basis), the pH decreases by 0.5 or more units to a value of 4.0 or less (1:1 by weight in water or in a minimum of water to permit measurement) within 16 weeks or longer until the pH reaches a nearly constant value if the pH is still dropping after 16 weeks; *or*

2. A pH value (1:1 in water) of more than 3.5 and 0.75 percent or more S (dry mass), mostly in the form of sulfides, and less than three times as much calcium carbonate equivalent as S.

Sulfuric Horizon

Brackish water sediments frequently contain pyrite or other iron sulfide minerals (or, rarely, elemental sulfur), which form sulfuric acid upon the oxidation of the sulfur forms they contain and/or upon the oxidation and hydrolysis of the iron in the iron sulfides. Pyrite is an iron sulfide mineral that forms as a result of the microbial decomposition of organic matter under anaerobic conditions. Pyrite forms after iron oxide and sulfate from sea water (or other sources) become reduced to ferrous iron and sulfide, respectively, and then combine to form a very insoluble compound (see description of the sulfidization process given by Fanning and Fanning, 1989, or Fanning et al., 2002). Characteristically, the pyrite crystals occur as nests or framboids composed of bipyramidal crystals of pyrite. In an oxidizing environment, pyrite oxidizes and the products of oxidation (and the hydrolysis of the ferric iron produced) are iron oxides (and under sufficiently acidic and oxidizing conditions, jarosite and/or schwertmannite) and sulfuric acid. The jarosite has a straw-yellow color and frequently lines pores in the soil. Jarosite concentrations are among the indicators of a sulfuric horizon, but jarosite is not present in all sulfuric horizons.

The low pH and high amount of soluble sulfates, and/or underlying sulfidic materials, are other indicators of a sulfuric horizon. A quick test of sulfidic materials is a rapid fall in pH on drying or after treatment with an oxidizing agent, such as hydrogen peroxide.

A sulfuric (L. *sulfur*) horizon forms as a result of drainage (most commonly artificial drainage) and oxidation of sulfide-rich mineral or organic soil materials. It can form in areas where sulfidic materials have been exposed as a result of surface mining, dredging, or other earth-moving operations. A sulfuric horizon is detrimental to most plants and, if sufficiently acid at the soil surface, may prevent plant growth or limit it to certain plant species, such as *Phragmites australis*, that can tolerate the acidity under certain conditions.

Required Characteristics

The sulfuric horizon is 15 cm or more thick and is composed of either mineral or organic soil material that has a pH value (1:1 by weight in water or in a minimum of water to permit measurement) of 3.5 or less *or* less than 4.0 if sulfide or other S-bearing minerals that produce sulfuric acid upon their oxidation are present. The horizon shows evidence that the low pH value is caused by sulfuric acid.

The evidence is *one or both* of the following:

1. The horizon has:

    a. Concentrations of jarosite, schwertmannite, or other iron and/or aluminum sulfates or hydroxysulfate minerals; *or*

    b. 0.05 percent or more water-soluble sulfate; *or*

2. The layer directly underlying the horizon consists of sulfidic materials (defined above).

Characteristics Diagnostic for Human-Altered and Human-Transported Soils

Following are descriptions of the characteristics that are diagnostic for human-altered and human-transported soils. The diagnostic surface and subsurface horizons that may be present in these soils are defined above.

Anthropogenic Landforms and Microfeatures

Anthropogenic Landforms

Anthropogenic landforms are discrete, artificial landforms that are mappable at common survey scales, such as 1:10,000 to 1:24,000. For more information on these terms, see Part 629 of the *National Soil Survey Handbook* (U.S. Department of Agriculture).

Constructional Anthropogenic Landforms

Constructional anthropogenic landforms include the following:

1. Artificial islands
2. Artificial levees
3. Burial mounds
4. Dumps
5. Dredge-deposit shoals
6. Dredge spoil banks
7. Filled marshland
8. Earthworks
9. Fill
10. Filled pits

11. Filled enclosures
12. Irrigationally raised land
13. Raised land
14. Landfills
15. Locally raised landforms
16. Middens
17. Mounds
18. Railroad beds
19. Reclaimed land
20. Rice paddies
21. Road beds
22. Sanitary landfills
23. Spoil banks
24. Spoil piles

Destructional Anthropogenic Landforms

Destructional anthropogenic landforms include the following:

1. Beveled cuts
2. Borrow pits
3. Canals
4. Cuts (i.e., road or railroad)
5. Cutbanks
6. Dredged channels
7. Earthworks
8. Floodways
9. Gravel pits
10. Leveled land
11. Log landings
12. Openpit mines
13. Quarries
14. Rice paddies
15. Sand pits
16. Scalped area
17. Sewage lagoons
18. Surface mines

Anthropogenic Microfeatures

Anthropogenic microfeatures are discrete, artificial features formed on or near the earth's surface (and which may now be buried) typically too small to delineate at common survey scales, such as larger than 1:10,000. For more information on these terms, see Part 629 of the *National Soil Survey Handbook* (U.S. Department of Agriculture).

Constructional Anthropogenic Microfeatures

Constructional anthropogenic microfeatures include the following:

1. Breakwater (i.e., groins or jetties)
2. Burial mounds
3. Conservation terraces
4. Dikes
5. Double-bedding mounds
6. Dumps
7. Embankments
8. Fills
9. Hillslope terraces
10. Interfurrows
11. Middens
12. Revetments (i.e., seawalls)
13. Rice paddies
14. Spoil banks
15. Spoil piles

Destructional Anthropogenic Microfeatures

Destructional anthropogenic microfeatures include the following:

1. Cutbanks
2. Ditches
3. Furrows
4. Hillslope terraces
5. Impact craters
6. Skid trails
7. Scalped areas

Artifacts

Artifacts (L. *arte*, by skill, and *factum*, to do or make) are materials created, modified, or transported from their source by humans usually for a practical purpose in habitation, manufacturing, excavation, agriculture, or construction activities. Examples of discrete (> 2mm) artifacts are bitumen (asphalt), brick, cardboard, carpet, cloth, coal combustion by-products, concrete, glass, metal, paper, plastic, rubber, and both treated and untreated wood products. Mechanically abraded rocks (e.g., rocks with metal scrape marks or gouges), rocks worn smooth or shaped by physical action (e.g., grinding stones), or physically broken and shaped rocks and debitage are artifacts (e.g., stone tool flakes). Examples of nonpersistent artifacts repeatedly added to soil to improve agricultural production include biosolids, aglime, quicklime, and synthetic inorganic fertilizers. Humans have also added midden material to the soil to increase agricultural productivity, but these additions (e.g., bones, shells, and cooking waste and associated charred by-products) have persisted to produce long-term (hundreds to thousands of years) changes in soil properties (e.g., Terra Preta de Indio soils). Artifacts also include litter discarded by humans (e.g., aluminum cans) that appears to serve no apparent purpose or function for alteration of soil.

Human-Altered Material

Human-altered material is parent material for soil that has undergone anthroturbation (soil mixing or disturbance) by humans. It occurs in soils that have either been used for gardening, been deeply mixed in place, excavated and replaced, or compacted in place for the artificial ponding of water.

Human-altered material may be composed of either organic or mineral soil material. It may contain artifacts (e.g., shells or bones) used as agricultural amendments, but the majority of the material has no evidence that it was transported from outside of the pedon.

Human-altered material occurs in soils which are disturbed for various reasons. For example, human-altered material occurs in agricultural soils which are deeply-plowed or ripped to disrupt a root-limiting layer (defined in chapter 17) or other physical restriction. Gravesites in cemeteries contain human-altered material as well as artifacts. Densic contacts form at the top of wet, slowly permeable (i.e., puddled) layers when they are compacted by humans and destroy structure and impede water percolation. Subsequent artificial ponding in such human-altered material results in anthric saturation (defined above) for the purpose of growing crops like rice in paddy soils.

Diagnostic horizons formed by significant illuviation (e.g., argillic or petrocalcic horizons) have not been documented as occurring in human-altered material. However, laterally tracing an illuvial horizon or diagnostic characteristic to find a discontinuity where the horizon or characteristic is abruptly absent can be used to identify human-altered material. The lateral discontinuity typically extends along linear boundaries. When the lateral discontinuity occurs at the edge of an anthropogenic landform or microfeature (defined above), it confirms the destructional origin of the landform or feature and identifies the human-altered material produced through excavation. It is often the preponderance of evidence (best professional judgment) along with published or historical evidence and onsite observations that allows the most consistent identification of excavated human-altered material.

Required Characteristics

Human-altered material meets *both* of the following:

1. It occurs in *one* of the following:

a. A field tilled with a subsoiler to a depth of 50 cm or more to break up an impermeable or root-restrictive layer; *or*

b. A destructional (excavated) anthropogenic landform or microfeature (e.g., borrow pit); *or*

c. A field ponded for agriculture (e.g., rice paddy); *and*

2. It does not meet the requirements of human-transported material (defined below) *and* has evidence of purposeful alteration by humans which results in *one* of the following:

a. 3 percent or more (by volume) mechanically detached and re-oriented pieces of diagnostic horizons or characteristics in a horizon or layer 7.5 cm or more thick; *or*

b. 50 percent or more (by volume) divergent-shaped structures (from L. *divergent*, to veer)‡ in a horizon or layer 7.5 cm or more thick formed from traffic or mechanical pressure exceeding the shear strength of moist loamy or clayey soil material; *or*

c. Excavated and replaced soil material overlying either bones or artifacts arranged in ceremonial position or human body parts prepared to prevent decay; *or*

d. Mechanically-abraded rock fragments; *or*

e. Excavated and replaced soil material unconformably overlying features (e.g., scrape marks) that indicate excavation by mechanical tools in some part of the pedon; *or*

f. An abrupt lateral discontinuity of subsurface horizons and characteristics at the edge of a refilled or unfilled destructional (excavated) anthropogenic landform or microfeature; *or*

g. Anthraquic conditions in a horizon or layer 7.5 cm or more thick; *or*

h. A densic contact or thick platy structure in at least 50 percent of a pedon accompanied by additional evidence (e.g., scrape marks) that it was formed by human-induced mechanical compaction.

Human-Transported Material

Human-transported material is parent material for soil that has been moved horizontally onto a pedon from a source area outside of that pedon by purposeful human activity, usually with the aid of machinery or hand tools. This material often contains a lithologic discontinuity or a buried horizon just below an individual deposit. In some cases it is not possible to distinguish between human-transported material and parent material from mass movement processes (e.g., landslides) without intensive onsite examination and analysis.

Human-transported material may be composed of either organic or mineral soil material and may contain detached pieces of diagnostic horizons which are derived from excavated soils. It may also contain artifacts (e.g., asphalt) that are not used as agricultural amendments (e.g., biosolids) or are litter discarded by humans (e.g., aluminum cans). Human-transported material has evidence that it did not originate from the same pedon which it overlies. In some soils, irregular distribution with depth or in proximity away from an anthropogenic landform, feature, or constructed object (e.g., a road or building) of modern products (e.g., radioactive fallout, deicers, or lead-based paint) may mark separate depositions of human-transported materials or mark the boundary with *in situ* soil material below or beside the human-transported material. In other soils, a discontinuity exists between the human-transported material and the parent material (e.g., a 2C horizon) or root-limiting layer (e.g., a 2R layer) beneath it. Multiple forms of evidence may be required to identify human-transported material where combinations of human actions and natural processes interact. Examples of these combinations include human-transported material deposited by dredging

‡ Surfaces that formed by shearing intersect irregularly in diverging and converging directions.

adjacent to active beaches, human- or water-deposited litter on flood plains and beneath water bodies, and deposits from natural geologic events (e.g., airfall volcanic ash) mantling anthropogenic landforms and microfeatures. Therefore, it is often the preponderance of evidence, including published or historical evidence and onsite observations, that allows identification of human-transported material.

Required Characteristics

Human-transported material meets *both* of the following:

1. It occurs *either*:

a. On a constructional anthropogenic landform or microfeature (e.g., artificial levees); *or*

b. Within the boundaries of a destructional (excavated) anthropogenic landform or microfeature (e.g., borrow pit); *and*

2. It has evidence of purposeful transportation by humans and an origin outside of the pedon by at least *one* of the following:

a. A layer of soil material 7.5 cm or more thick which unconformably overlies material that has no evidence of originating outside of the pedon (e.g., an *in situ*, laterally continuous kandic horizon); *or*

b. Artifacts other than agricultural amendments (e.g., quicklime) and litter discarded by humans (e.g., aluminum cans); *or*

c. Mechanically detached pieces of diagnostic horizons or characteristics or saprolite (isovolumetric, weathered, uncemented pseudomorphs of weathered bedrock) that do not correspond with the underlying material. The pieces often have random orientation relative to each other and the soil surface and contrast abruptly in texture, mineralogy, or color with the surrounding material; *or*

d. Soil material that contains mechanically abraded rock or pararock fragments; *or*

e. Mechanically fractured rock or pararock fragments with splintered or sharp edges that do not correspond with the fragments in the underlying soil material (i.e., fractures that cut through rather than between individual minerals); *or*

f. Mechanical scrape marks at some part of the boundary between materials that do not correspond with each other; *or*

g. Soil material 7.5 cm or more thick that overlies a manufactured layer contact; *or*

h. Bridging voids[§] between rock fragments in a horizon or layer 7.5 cm or more thick in mine spoil with at least 35 percent (by volume) rock fragments; *or*

i. An irregular distribution pattern of modern anthropogenic particulate artifacts (e.g., radioactive fallout or immobile pollutants) or discrete artifacts that are unrelated to the deposition or transportation processes of natural parent materials such as eolian material, alluvium, or colluvium. The irregular distribution occurs above or across the contact between soil materials that do not correspond with each other or laterally with distance away from a source (e.g., the amount of lead-based paint decreases away from a building).

Manufactured Layer

A manufactured layer is an artificial, root-limiting layer beneath the soil surface consisting of nearly continuous, human-manufactured materials whose purpose is to form an impervious barrier. The materials used to make the layer impervious include geotextile liners, asphalt, concrete, rubber, and plastic. The presence of manufactured layers can be used to differentiate soil series.

Manufactured Layer Contact

A manufactured (L. *humanus*, of or belonging to man, and L. *factum*, to do or make) layer contact is an abrupt contact between soil and a manufactured layer (defined above). It has no cracks, or the spacing of cracks that roots can enter is 10 cm or more.

Subgroups for Human-Altered and Human-Transported Soils

The following subgroup adjectives recognize distinct groups of human-altered and human-transported soils. Soils using these adjectives are considered extragrades since they do not represent an intergrade to any other named taxon (Soil Survey Staff, 1999). They are listed in order of interpretive significance as a guide, but the significance and order may change slightly depending on the great group in which they are recognized. They are not used in combination with each other even though some soils may have properties of several subgroups. These adjectives may be combined alphabetically with adjectives connoting other soil properties, such as high organic matter content (e.g., Anthropic Humic) or the presence of sulfidic materials (e.g., Anthroportic Sulfic), to form the names for additional extragrade subgroups. Additional adjectives for other properties will generally increase the importance of the subgroup and result in higher placement within a key to subgroups.

1. **Anthraquic** (modified from Gr. *anthropos*, human, and L. *aqua*, water). Soils that have anthraquic conditions (i.e., anthric saturation). These soils are extensive in flooded rice paddies.

[§] A void created when soil materials with a high content of rock fragments are transported and deposited without packing or sorting. The result is a trio of rock fragments stacked in a manner than prevents fine earth from filling the void.

2. **Anthrodensic** (modified from Gr. *anthropos*, human, and L. *densus*, marked by compactness). Soils that have a densic contact due to mechanical compaction (e.g., a compacted mine spoil) in more than 90 percent of the pedon (measured laterally) within 100 cm of the mineral soil surface.

3. **Anthropic** (modified from Gr. *anthropos,* human). Soils that have an anthropic epipedon based on the presence of artifacts or midden material.

4. **Plaggic** (modified from Ger. *plaggen*, sod). Soils that have a plaggen epipedon.

5. **Haploplaggic** (Gr. *haplous*, simple, and Ger. *plaggen*, sod). Soils that have a surface horizon 25 cm to less than 50 cm thick that meets all of the requirements for a plaggen epipedon except thickness.

6. **Anthroportic** (modified from Gr. *anthropos,* human, and L. *portāre,* to carry). Soils that formed in 50 cm or more of human-transported material. This adjective is used primarily for soils that formed in human-transported material of dredged or mine spoil areas as well as for soils of urban areas and transportation corridors.

7. **Anthraltic** (modified from Gr. *anthropos*, human, and L. *alterāre*, to change). Soils that formed in 50 cm or more of human-altered material. This adjective is used primarily for human-altered material where ripping or deep plowing has fractured and displaced diagnostic subsurface horizons that were root-limiting (e.g., duripans) and in excavated areas (e.g., borrow pits).

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