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Field Extract of SOIL TAXONOMY

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PREFACE

Since the publication in 1975 of "Soil Taxonomy (Agriculture Handbook No.436, Soil Conservation Service, U.S. Department of Agriculture) it became apparent that there was a need for a small and handy book containing the essentials of the system, which could be used with more ease in the field than the original edition.

In 1978 such a pocket book was prepared for internal use by the International Institute for Aerial Survey and Earth Sciences (ITC) in co-operation with the International Soil Museum The specific requirements for students' exercises were taken as a guiding principle. As a result the booklet became somewhat unbalanced with some definitions included in detail and others omitted.

The present edition is intended for wider use. Definitions of all diagnostic characteristics are included in a shortened form. Family differentiae are given in full as well as the keys to orders, suborders and great groups. Relevant sections of the "Approved Amendments and Clarification of Definitions" (May 5, 1978) are given in the Appendix.

The reader is cautioned that the original text, notably the part dealing with the diagnostic characteristics, has been considerably shortene and stripped of any discussion and examples. For full details the original text should be consulted.

Grateful acknowledgement is due to Dr. K. Flach Assistant Administrator for Soil Survey of the USDA/SCS for his permission to put this Field Extract on sale at the International Soil Museum.

Wageningen, September 1980

Dr. W.G. Sombroek
Director ISM

Horizons and Properties Diagnostic for the Higher Categories: Mineral Soils

Mineral soil material

Mineral soil material either
1. Is never saturated with water for more than a few days and has <20 percent organic carbon by weight; or
2. Is saturated with water for long periods or has been artificially drained, and has
   a. Less than 18 percent organic carbon by weight if 60 percent or more of the mineral fraction is clay;
   b. Less than 12 percent organic carbon by weight if the mineral fraction has no clay; or
   c. A proportional content of organic carbon between 12 and 18 percent if the clay content of the mineral fraction is between zero and 60 percent.

Soil material that has more organic carbon than the amounts just given is considered to be organic material.

Definition of mineral soils

Mineral soils, in this taxonomy, are soils that meet one of the following requirements:
1. Mineral soil material <2mm in diameter (the fine-earth fraction) makes up more than half the thickness of the upper 80 cm (31 in.);
2. The depth to bedrock is <40 cm and the layer or layers of mineral soil directly above the rock either are 10 cm or more thick or have half or more of the thickness of the overlying organic soil material; or
3. The depth to bedrock is ≥40 cm, the mineral soil material immediately above the bedrock is 10 cm or more thick, and either
   a. Organic soil material is <40 cm thick and is decomposed (consisting of hemic or sapric materials as defined later) or has a bulk density of 0.1 or more; or
   b. Organic soil material is <60 cm thick and either is undecomposed sphagnum or moss fibers or has a bulk density that is <0.1.

Diagnostic surface horizons; the epipedon

Six diagnostic horizons that form at the surface are defined. Any horizon, however, may be at the surface of a truncated soil. A horizon that forms at the surface is called an epipedon (Gr. *epi*, over or upon, and *pedon*, soil). The epipedon not only has formed at the surface but it also has been either appreciably darkened by organic matter or eluviated or, as a minimum, rock structure has been destroyed. Such a horizon may become covered by thin deposits of fresh alluvium or by thin eolian deposits without losing its identity as an epipedon. The depth to which an epipedon must be buried to be considered part of a buried soil is defined below. Generally a buried horizon lies below a depth of 50 cm or more, usually more.

A recent alluvial or eolian deposit that retains fine stratifications or an Ap horizon that is directly underlain by material that retains fine stratifications are 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.

The epipedon is not a synonym for the A horizon because it may include part or all of the illuvial B horizon if the darkening by organic matter extends from the surface into or through the B horizon.

To avoid changes in classification of a soil as the result of plowing, the properties of the epipedon, except for structure, should be determined after the surface soil to a depth of 18 cm has been mixed or, if the depth to bedrock is <18 cm, after the whole soil down to rock has been mixed.

Buried soils

A soil is considered to be a buried soil if there is a surface mantle of new material that is 50 cm or more thick or if there is a surface mantle between 30 and 50 cm thick and the thickness of the mantle is at least half that of the named diagnostic horizons that are preserved in the buried soil. A mantle that is <30 cm thick is not considered in the taxonomy but, if important to the use of the soil, is considered in establishing a phase. The soil that we classify in places where a mantle is present, therefore, has its upper boundary at the surface or <50 cm below the surface, depending on the thickness of its horizons.

A surface mantle of new material as defined here is largely unaltered. It is usually finely stratified and overlies a horizon sequence that can be clearly identified as the solum of a buried soil in at least part of the pedon, as defined in the following chapter. The recognition of a surface mantle should not be based solely on studies of associated soils.

Mollic epipedon (L. *mollis*, soft)

Properties

The mollic epipedon is defined in terms of its morphology rather than its genesis. It consists of mineral soil material. It is a surface horizon or horizons unless (a) it underlies a recent deposit that is <50 cm thick and that has fine stratifications if not plowed or (b) it underlies a thin layer of organic material in a wet soil (see histic epipedon). If the layer of organic material is thick enough that the soil is organic, the mineral soil is considered to be buried.

The mollic epipedon has the following properties:

1. Soil structure is strong enough that the major part of the horizon is not both massive and hard or very hard when dry. Very coarse prisms, >30 cm in diameter, are included in the meaning of massive if there is no secondary structure within the prisms.
2. Unless there is >40 percent finely divided lime, both broken and crushed samples have Munsell color

value darker than 3.5 when moist and 5.5 when dry, and chroma less than 3.5 when moist;[1] the color value normally is at least 1 Munsell unit darker or the chroma is at least 2 units less (both moist and dry) than that of the IC horizon if an IC horizon is present. If only a IIC horizon or an R layer is present, the comparison should be made with the horizon that overlies the IIC. Some parent materials such as loess, cinders, alluvium, or carbonaceous shales also can have dark color and low chroma. Soils formed in such materials may accumulate appreciable amounts of organic matter but have no visible darkening in the epipedon. In this situation, the requirement that the mollic epipedon have lower value or chroma than the IC horizon, or than the next underlying horizon if there is no IC, is waived if (a) the surface horizon (horizons) meets all other requirements for a mollic epipedon and, in addition, has at least 0.6 percent more organic carbon than the IC or the IIC horizon or if (b) the epipedon extends to rock (either a lithic or paralithic contact as defined later).

The mollic epipedon is expected to have dark color and low chroma throughout the major part of its matrix. If the structure is fine granular or fine blocky, the color when broken may be only the color of the coatings. The color of the matrix in such situations can be determined only by crushing or briefly rubbing the sample. Prolonged rubbing should be avoided because it may cause darkening of a sample if soft iron-manganese concretions are present; crushing should be only enough to break and mix the coatings. The color value when dry should be determined after the crushed sample has been smoothed to eliminate shadows.

If there is >40 percent finely divided lime, the limits of color value, dry, are waived; the color value, moist, then should be 5 or less. This waiver is necessary because finely divided lime acts as a white pigment.

3. Base saturation is 50 percent or more by the NH_4OAc method (see appendix IV).

4. The organic-carbon content is 2.5 percent or more in the upper 18 cm if the color requirement is waived because of finely divided lime. Otherwise, the organic-carbon content is at least 0.6 percent (1 percent organic matter) throughout the thickness of soil specified in item 5.

The mollic epipedon consists of mineral rather than organic soil material. Its organic-carbon content, therefore, has an upper as well as a lower limit. The upper limit of organic carbon in a mollic epipedon is the same as that of mineral soil material; in part it is the lower limit for the histic epipedon, defined later in this chapter. Because an organic horizon can form above a mollic epipedon in a wet soil, the mollic epipedon is not necessarily the surface horizon but is the uppermost horizon composed of mineral soil material.

5. The thickness is one of the following after mixing

[1] The chroma is permitted to range up to but not to include 4.0 in soils that have a hyperthermic or isohyperthermic temperature regime. The color when moist is that of a specimen that is moist enough that an additional drop of water produces no change in the color. The color when dry is that of a specimen dry enough that continued drying produces no further change.

the upper 18 cm of soil or the whole soil if the depth to rock, petrocalcic horizon, or duripan is <18 cm:

a. Ten cm or more if the epipedon is underlain directly by a lithic contact; 10 cm or more in soils of shallow families in which the epipedon is underlain directly by a paralithic contact, a petrocalcic horizon, or a duripan, all defined later in this chapter;

b. In other soils the epipedon must be >25 cm thick if its texture is finer than loamy fine sand and

(1) The upper boundary of pedogenic lime that is present as filaments, soft coatings, or soft nodules is deeper than 75 cm;

(2) The base of any argillic, natric, spodic, cambic, or oxic horizon is deeper than 75 cm; and

(3) The upper boundary of any petrocalcic horizon, fragipan, or duripan is deeper than 75 cm;

c. In other soils that have a loamy or clayey epipedon, the thickness of the epipedon must be 18 cm or more and it must be more than one-third of the depth from the top of the epipedon to the shallowest of one of the features listed in (b) if that is <75 cm;

d. In other soils the epipedon must be >25 cm thick if

(1) The texture of the epipedon is as coarse as or coarser than loamy fine sand throughout its thickness or

(2) If there are no underlying diagnostic horizons and the organic-carbon content of the underlying materials decreases irregularly with increasing depth (as in recent alluvium that is not finely stratified) ; or

e. In other soils, the epipedon must be 18 cm (7 in.) or more thick if none of the conditions that are listed in *b*, *c*, and *d* exist.

6. The epipedon has <250 parts per million (ppm) of P_2O_5 soluble in 1 percent citric acid or it either has increasing amounts of P_2O_5 soluble in citric acid below the epipedon or has phosphate nodules in the epipedon. This restriction is made to eliminate plow layers of very old arable soils and kitchen middens that have acquired, under use, the properties of the mollic epipedon but to include the epipedon of a soil developed in highly phosphatic parent material.

7. If the soil is not irrigated, some part of the epipedon is moist 3 months or more of the year (cumulative) in more than 7 out of 10 years at times when the soil temperature at a depth of 50 cm is 5° C or higher.

8. The n value (defined later in this chapter) is <0.7. Although many soils that have a mollic epipedon are very poorly drained, a mollic epipedon does not have the very high water content of sediments that have been continuously under water since deposition.

Anthropic epipedon

In summary, the anthropic epipedon conforms to all the requirements of the mollic epipedon except (1) the limits on acid-soluble P_2O_5, with or without the base saturation, or (2) the length of the period during which it has available moisture. Additional data on anthropic epipedons from several parts of the world may permit improvements in this definition.

Umbric epipedon (L. *umbra*, shade, hence dark)

Requirements of the umbric epipedon are comparable to those of the mollic epipedon in color, organic-carbon and phosphorus content, consistence, structure, *n* value, and thickness. The umbric epipedon includes those thick, dark-colored surface horizons that have base saturation of <50 percent (by NH_4OAc). It should be noted that the restriction against a hard or very hard and massive epipedon when dry is applied only to those epipedons that become dry. If the epipedon is always moist, there is no restriction on its consistence or structure when dry. It should also be noted that some plaggen epipedons, defined later, meet all these requirements but also have evidences of slow addition of materials under cultivation. The umbric epipedon does not have the artifacts, spade marks, and raised surfaces that are evidences of slow additions in the plaggen epipedon.

Histic epipedon (Gr. *histos*, tissue)

The histic epipedon normally is at the surface, although it may be buried at a shallow depth. It normally is a thin horizon of peat or muck if the soil has not been plowed. If the soil has been plowed, the histic epipedon has the very high content of organic matter that results from mixing peat with some mineral material. Since peaty deposits occur in wet places, the histic epipedon either is saturated with water for 30 consecutive days or more during the year or has been artificially drained.

The histic epipedon, therefore, can be defined as a layer (one horizon or more) at or near the surface that is saturated with water for 30 consecutive days or more at some time in most years, or is artificially drained, and that meets one of the following requirements:

1. The surface horizon consists of organic soil material that either
   a. Is 75 percent or more, by volume, sphagnum fibers or has a bulk density, when moist, <0.1 and is <60 cm (24 in.) but >20 cm thick; or
   b. Is <40 cm but >20 cm thick and meets one of the following requirements with respect to organic-carbon content and thickness:
      (1) Has 18 percent or more organic carbon if the mineral fraction is 60 percent or more clay;

(2) Has 12 percent or more organic carbon if the mineral fraction has no clay;

(3) Has an intermediate proportional content of organic carbon if part but less than 60 percent of the mineral fraction is clay.

2. The plow layer is 25 cm or more thick and has 8 percent or more organic carbon if it has no clay, or 16 percent or more organic carbon if 60 percent or more of the mineral fraction is clay, or an intermediate proportional content of organic carbon if part but less than 60 percent of the mineral fraction is clay.
3. A layer of organic material that has enough organic carbon and is thick enough to satisfy one of the requirements under item 1 lies beneath a surface layer of mineral materials that is <40 cm (16 in.) thick. In such a soil, the histic epipedon has been buried but the mineral materials at the surface are too thin to be considered diagnostic in the classification.
4. A surface layer of organic material <25 cm thick that has enough organic carbon to satisfy the minimum requirements under item 2 after the soil has been mixed to a depth of 25 cm.

Plaggen epipedon (Ger. *plaggen*, sod)

The plaggen epipedon is a manmade surface layer 50 cm (20 in.) or more thick that has been produced by long-continued manuring.

The color of a plaggen epipedon and its organic-carbon content depend on sources of the materials used for bedding.

The plaggen epipedon can be identified by several means. Commonly it contains artifacts, such as bits of brick and pottery, throughout its depth. Chunks of diverse materials, such as black sand and light gray sand, as large as the size held by a spade may be present. The plaggen epipedon normally shows spade marks throughout its depth and also remnants of thin stratified beds of sand that probably were produced on the surface by beating rains and later were buried by spading.

Ochric epipedon (Gr. *ochros*, pale)

An ochric epipedon is one that is too high in value or chroma, is too dry, has too little organic matter, has an n value too high, or is too thin to be mollic, umbric, anthropic, plaggen, or histic, or it is both hard and massive when dry. An epipedon is ochric if the Munsell color value after rubbing is 5.5 or higher when dry or 3.5 or higher when moist, if the chroma is 3.5 or more [2], or if the A1 or the Ap horizon that has both low value and low chroma is too thin to be a mollic or an umbric epipedon. Epipedons that have a color value after rubbing lower than 5.5, dry, and lower than 3.5, moist, are also ochric provided they are no darker than the IC horizon and do not have as much as 0.6 percent more organic carbon than the IC horizon. The ochric epipedon includes eluvial horizons that are at or near the surface (the A2 horizon and an albic horizon, which is defined later) and extends to the first underlying diagnostic illuvial horizon (defined later as an argillic, natric, or spodic horizon). If the underlying horizon is a B horizon of alteration (defined later as a cambic or an oxic horizon) and there is no surface horizon that is appreciably darkened by humus, the most convenient lower limit of the ochric epipedon is the base of the plow layer or an equivalent depth in a soil that has not been plowed. Actually, the same subhorizon in an unplowed soil may be both a part of the epipedon and a part of the cambic horizon. The epipedon and the subsurface diagnostic horizons are not mutually exclusive. The ochric epipedon does not have rock structure. It does not include fresh sediments that are finely stratified.

Diagnostic subsurface horizons

The horizons discussed in this section form below the surface of the soil, although in some places they form immediately below a layer of leaf litter. They may be exposed at the surface by truncation of the soil. Some of these horizons are generally considered to be B horizons; some are considered B horizons by many but not all pedologists; others are generally considered to be parts of the A horizon.

Argillic horizon

Summary of properties

In summary, we can say that an argillic horizon is one that contains illuvial layer-lattice clays. This horizon forms below an eluvial horizon, but it may be at the surface if a soil has been partially truncated. It has the following properties that can be used for identification:

1. If an eluvial horizon remains and if there is no lithologic discontinuity between it and the argillic horizon, the argillic horizon contains more total clay and more fine clay than the eluvial horizon, as follows. The increases in clay are reached within a vertical distance of 30 cm or less.
    a. If any part of the eluvial horizon has <15 percent total clay in the fine-earth fraction (<2 mm), the argillic horizon must contain at least 3 percent more clay (13 percent versus 10 percent, for example). The ratio of fine clay to total clay normally is greater in the argillic horizon than in the overlying eluvial horizons or the underlying horizon by about one-third or more.
    b. If the eluvial horizon has >15 percent and <40 percent total clay in the fine-earth fraction, the ratio of clay in the argillic horizon to that in the eluvial horizon must be 1.2 or more. The ratio of fine clay to total clay in the argillic horizon is normally greater than in the eluvial horizon by about one-third or more.
    c. If the eluvial horizon has >40 percent total clay in the fine-earth fraction, the argillic horizon must contain at least 8 percent more clay or, if the total clay content exceeds 60 percent, 8 percent more fine clay (50 percent versus 42 percent, for example).
2. An argillic horizon should be at least one-tenth as thick as the sum of the thickness of all overlying horizons, or it should be 15 cm or more thick if the eluvial and illuvial horizons together are more than 1.5 m thick. If the argillic horizon is sand or loamy sand, it should be at least 15 cm thick. If it is composed entirely of lamellae, lamellae ≥ 1 cm thick should have a combined thickness of at least 15 cm. If the argillic horizon

is loamy or clayey, it should be at least 7.5 cm thick.
3. In structureless soils, the argillic horizon has oriented clay bridging the sand grains and also in some pores.
4. If peds are present, an argillic horizon should meet one of the following requirements:

a. Have clay skins on some of both the vertical and horizontal ped surfaces and in the fine pores or have oriented clay in 1 percent or more of the cross section;
b. Meet requirements 1 and 2 and also have a broken or irregular upper boundary and some clay skins in the lowest part of the horizon;
c. If the horizon is clayey, if the clay is kaolinitic, and if the surface horizon has >40 percent clay, have some clay skins on peds and in pores in the lower part of the horizon that has blocky or prismatic structure; or
d. If the illuvial horizon is clayey with 2-to-1 lattice clays, an argillic horizon does not need to have clay skins if there are uncoated grains of sand or silt in the overlying horizon and evidences of pressure caused by swelling or if the ratio of fine to total clay in the horizon is greater by at least one-third than the ratio in the overlying or the underlying horizon or if it has >8 percent more fine clay. The evidences of pressure may be occasional slickensides or wavy horizon boundaries in the illuvial horizon.

5. If a soil has a lithologic discontinuity between the eluvial horizon and the argillic horizon or if only a plow layer overlies the argillic horizon, the argillic horizon needs to have clay skins in only some part, either in some fine pores or, if peds exist, on some vertical and horizontal ped surfaces. Either thin sections should show that some part of the horizon has about 1 percent or more of oriented clay bodies or the ratio of fine clay to total clay should be greater than in the overlying or the underlying horizon.

Agric horizon

The agric horizon (L. *ager*, field) is an illuvial horizon formed under cultivation that contains significant amounts of illuvial silt, clay, and humus.

After long-continued cultivation, changes in the horizon immediately below the plow layer become apparent and cannot be ignored in classifying the soil. The worm channels, root channels, or ped surfaces become coated with a dark-colored mixture of organic matter, silt, and clay. The accumulation on the sides of wormholes becomes thick and eventually can fill them. If worms are scarce, the accumulation may take the form of thick lamellae that may range in thickness from a few millimeters to about 1 cm. The coatings on the sides of wormholes and lamellae always have lower color value and chroma than the soil matrix.

The agric horizon has somewhat different forms in different climates if there are differences in soil fauna. In a humid temperate climate, where soils have what is later defined as a udic moisture regime and a mesic temperature regime, earthworms can become abundant. If there are earthworm holes that, with their coatings, constitute 5 percent or more of the volume and if the coatings are 2 mm or more thick and have color value of 4 or less and chroma of 2 or less, moist, the horizon is considered an agric horizon. After long-continued cultivation, the content of organic matter is not likely to be high, but the carbon-nitrogen ratio in the agric horizon is low, usually <8. The pH of the agric horizon is close to neutrality, 6 to 6.5.

In a Mediterranean climate, where soils have what is later defined as a xeric soil moisture regime, earthworms are less common and the illuvial materials accumulate as lamellae directly below the Ap horizon. If the lamellae are 5 mm or more thick, have color value of 4 or less, moist, and chroma of 2 or less, and constitute 5 percent or more by volume of a horizon that is 10 cm or more thick, the horizon is considered an agric horizon.

Natric horizon

The natric horizon (NL. *natrium*, sodium; implying presence of sodium) is a special kind of argillic horizon. It has, in addition to the properties of the argillic horizon:

1. Either
   a. Prisms or, more commonly, columns in some part, usually the upper part, that may or may not break to blocks; or
   b. Rarely, blocky structure and tongues of an eluvial horizon, in which there are uncoated silt or sand grains, extending more than 2.5 cm into the horizon; and
2. Either
   a. The SAR[3] is $\geq$ 13 (or 15 percent or more saturation with exchangeable sodium) in some subhorizon within 40 cm of the upper boundary; or
   b. More exchangeable magnesium plus sodium than calcium plus exchange acidity (at pH 8.2) in some subhorizon within 40 cm of the upper boundary if the SAR is $\geq$13 (or ESP $\geq$15) in some horizon within 2 m of the surface.

Sombric horizon

The sombric horizon is a subsurface horizon of mineral soils 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 of a spodic horizon relative to clay, and it does not have the high base saturation of a natric horizon. The sombric horizon does not underlie an albic horizon.

[3] The percentage of exchangeable sodium (ESP) is used in the definition of the natric horizon and in a number of the taxa. Since this text was written, the U.S. Salinity Laboratory (personal communication from C. A. Bower) has revised its definition of sodic (alkali) soils and the method for measuring the sodium adsorption ratio (SAR) as follows: SAR is measured by the normal method if the conductivity (EC) of the saturation extract is <20 mmhos per cm at 25° C. If the conductivity is $\geq$20 mmhos and SAR is >10, SAR is determined on a sample that has been leached with distilled water until EC of the leachate decreases to about 4 mmhos per centimeter but not to <4. ESP of $\geq$15 is replaced by SAR of $\geq$13 if EC is large enough to require a correction for soluble salts in calculating ESP. If EC is low enough ($\leq$4) that no correction is needed for soluble salts, ESP is determined directly from the replaced cations.

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

The sombric horizon has lower color value or chroma, or both, than the overlying horizon and commonly, but not necessarily, contains more organic matter than the overlying horizon. It may have formed in an argillic, a cambic, or, possibly, an oxic horizon. If peds are present, the dark colors are most pronounced on ped surfaces.

A sombric horizon is easily confused in the field with a buried A1 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 through the matrix.

Spodic horizon

Summary of the limits of a spodic horizon

A spodic horizon is normally a subsurface horizon that underlies an O, A1, Ap, or A2 horizon. It may, however, meet the definition of an ochric or umbric epipedon. A spodic horizon has the morphological or the chemical and physical characteristics that are listed next, and its hue and chroma remain constant with increasing depth or the subhorizon that has the reddest hue or the highest chroma is near the top of the horizon. The color changes within 50 cm from the top of the horizon.[6] If the soil temperature regime is frigid or warmer, some part of the spodic horizon must meet one or more of the following requirements below a depth of 12.5 cm or below any Ap horizon that is present. If the soil temperature regime is cryic or pergelic, there is no requirement for depth. In addition, the spodic horizon must meet one or more of the following requirements:

1. Have a subhorizon >2.5 cm thick that is continuously cemented by some combination of organic matter with iron or aluminum or with both;
2. Have a particle-size class that is sandy or coarse-loamy, and sand grains are covered with cracked coatings or there are distinct dark pellets of coarse-silt size, or both; or
3. Have one or more subhorizons in which
   a. If there is 0.1 percent or more extractable iron, the ratio of iron plus aluminum (elemental) extractable by pyrophosphate at pH 10 to percentage of clay is ≥ 0.2 (percentage of pyrophosphate-extractable Fe + Al at pH 10 ÷ clay percentage ≥ 0.2) or if there is <0.1 percent extractable iron, the ratio of aluminum plus carbon to clay is ≥ 0.2 (percentage of pyrophosphate-extractable Al + C ÷ clay percentage ≥ 0.2); and
   b. The sum of pyrophosphate-extractable iron plus aluminum is half or more of the sum of dithionite-citrate extractable iron plus aluminum (percentage of pyrophosphate-extractable Fe + Al ÷ percentage of dithionate-citrate extractable Fe + Al $\geq$ 0.5) ; and

[6] A thin black horizon that has color value of 2 or less may overlie this horizon.

c. The combined index of accumulation of amorphous material must be 65 or more. The index for each subhorizon is calculated by subtracting half of the clay percentage from CEC at pH 8.2 and multiplying the remainder by the thickness of the subhorizon in centimeters. The results for all subhorizons are then added and the total must be 65 or more.

Placic horizon

The placic horizon (Gr. base of *plax*, flat stone; meaning a thin cemented pan) is a thin, black to dark reddish pan cemented by iron, by iron and manganese, or by an iron-organic matter complex. Its thickness ranges generally from 2 mm to 10 mm. Rarely, it is as thin as 1 mm or as thick as 20 to 40 mm in spots. It may be, but not necessarily, associated with stratification in parent materials. It is in the solum, roughly parallel to the soil surface, and is commonly within the upper 50 cm of the mineral soil. It has a pronounced wavy or even convolute form. It normally occurs as a single pan, not as multiple sheets one underlying another, but in places it may be bifurcated. It is a barrier to water and roots.

An iron-cemented pan is strong brown to dark reddish brown. A pan cemented by iron and manganese or by iron-organic matter complexes is black or reddish black. A single pan may contain two or more layers cemented by different agents. Iron-organic matter cements commonly are present in the upper part of the pan.

Identification is seldom difficult. The hard brittle pan differs so much from the material in which it occurs and is so close to the surface of the mineral soil material that it is obvious unless its thickness is minimal. A few analyses of placic horizons show that organic carbon is present in amounts ranging from 1 percent to 10 percent or more. The presence of organic carbon as well as the shape and position of the pan distinguish the placic horizon from the ironstone sheet that may form where water hangs or moves laterally at a lithologic discontinuity.

Cambic horizon

The cambic horizon is an altered horizon in which the texture of the fine-earth fraction is very fine sand, or loamy very fine sand or finer. Physical alteration is the result of (1) movement of the soil particles by frost, roots, or animals to such extent as to destroy most of the original rock structure, including the fine stratification of silt, clay, and very fine sand in alluvial or lacustrine deposits, or (2) aggregation of the soil particles into peds, or both. Chemical alteration has occurred also and is the result of (1) hydrolysis of some of the primary minerals to form clays and liberate sesquioxides, (2) solution and redistribution or removal of some carbonates, or (3) reduction and segregation or removal of free iron oxides along with biologic decomposition of inherited organic matter.

The cambic horizon has lost sesquioxides or bases, including carbonates, or both, through leaching. Gains may have occurred in organic matter and water, but the alteration of the cambic horizon is not the result of additions of mineral substances by illuviation.

A cambic horizon is at the surface in some truncated soils. Otherwise, it is immediately below one of the diagnostic epipedons. It is considered a part of the solum, and it occurs within the zone that normally is reached by roots of native plants. Thus, it normally lies in the position of a B horizon and is considered to be a B horizon in this system of soil classification. Its base must be at least 25 cm (10 in.) below the surface unless the soil temperature regime is cryic or pergelic.

Summary of properties

In summary, the cambic horizon is an altered horizon that does not have the dark color, organic-matter content, and structure that are definitive of a histic, a mollic, or an umbric epipedon, and it has

1. Texture that is very fine sand, loamy very fine sand, or finer in the fine-earth (<2 mm) fraction;
2. Soil structure or absence of rock structure in at least half the volume;
3. Significant amounts of weatherable minerals that consist of (a) enough amorphous or 2:1 lattice clay to give a cation-exchange capacity (by NH_4OAc) of more than 16 meq per 100 g clay, or (b) >3 percent weatherable minerals other than muscovite, or (c) >6 percent muscovite;
4. Evidence of alteration in one of the following forms:
   a. Gray colors as defined on page 34 an aquic moisture regime, defined later, or artificial drainage, and one or more of the following properties:
      (1) A regular decrease in the amount of organic carbon with depth and a content of <0.2 percent organic carbon at a depth of 1.25 m below the surface or immediately above a sandy-skeletal substratum that is at a depth of <1.25 m;
      (2) Cracks that open and close in most years and are 1 cm or more wide at a depth 50 cm below the surface;
      (3) Permafrost at some depth;
      (4) A histic epipedon consisting of mineral soil materials or a mollic or umbric epipedon;
   b. Stronger chroma, redder hue, or higher clay content than the underlying horizon;
   c. Evidences of removal of carbonates. Particularly, the cambic horizon has less carbonate than the underlying ca horizon. If all coarse fragments in the ca horizon are completely coated with lime, some in the cambic horizon are partly free of coatings. If coarse fragments in the ca horizon are coated only on the under side, those in the cambic horizon should be free of coatings;
   d. If carbonates are absent in the parent material and in the dust that falls on the soil, the required evidence of alteration is satisfied by the presence of soil structure and the absence of rock structure if the moisture regime is not aquic or the chroma is higher than those listed on p. 34;
5. Properties that do not meet the requirements of an argillic or a spodic horizon;
6. No cementation or induration and no brittle consistence when moist; and
7. Enough thickness that its base is at least 25 cm (10 in.) below the soil surface unless the soil temperature regime is cryic or pergelic.

Oxic horizon

The oxic horizon is intended to characterize a mineral subsurface horizon in an advanced stage of weathering. It is an altered subsurface horizon at least 30 cm (12 in.) thick. It consists of a mixture of hydrated oxides of iron or aluminum, or both, with variable amounts of 1:1 lattice clay [10] and accessory highly insoluble minerals such as quartz sand. Its fine-earth fraction has few or no primary minerals that can weather to release bases, iron, or aluminum. For each 100 grams of clay that it contains, the fine earth holds 10 meq or less of cations from an unbuffered 1N NH_4Cl solution and has a cation-exchange capacity, by NH_4OAc, of 16 meq or less per 100 g clay. The oxic horizon has a lower exchange capacity or a smaller amount of weatherable minerals than the cambic horizon. It differs from the argillic horizon in having few or no clay skins and in having either no increase or a gradual or diffuse increase in the percentage of clay at increasing depth. Its upper boundary is set at the least depth at which the cation-exchange capacity requirements of the oxic horizon are met, but not above 15 cm or the base of the Ap horizon. For diagnostic purposes, its lower boundary is usually set at a depth of 2 m.

Identification in the field.—Oxic horizons resemble cambic horizons in many respects, particularly those cambic horizons that approach the oxic horizon in degree of alteration of primary minerals. There are, nevertheless, several properties that can be used in the field for identification of an oxic horizon.

First are structure and consistence. Most oxic horizons appear massive in fresh pits, but many have very weak, very coarse prismatic structure that is visible only in old cuts. Some have weak coarse or medium blocky structure. A fragment of a few cubic centimeters of an oxic horizon, either moist or dry, crushes easily between the fingers to very fine granules. Most of these granules are very stable and are <1 mm in diameter. Commonly they can be seen only under a hand lens. A fragment, if moist, crushes before there is any visible deformation of the fragment as a whole, indicating low plasticity and high friability.

Boundaries of subhorizons within the oxic horizon normally are diffuse except those of subhorizons that contain a stone line, plinthite, or sheets of gibbsite. Changes in color and texture with depth are considerable in some soils but are so gradual that the boundaries are difficult to locate; boundaries of subhorizons generally are arbitrary. Unless a stone line is present, the boundary with the underlying material as a rule is equally gradual or diffuse.

Pores visible to the eye or under a hand lens are common to abundant in oxic horizons. The stability of these pores presumably reflects the stability of aggre-

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[10] Recent studies of Oxisols and other very old soils suggest that one 2:1 lattice clay either is extremely resistant to weathering in a humid climate, perhaps more so than kaolin, or has formed from dust that accumulated slowly over the millenia. This is an Al-interlayered chlorite. It has a 14Å reflection but will not collapse to 10 Å on potassium saturation and heating. It is commonly present in oxic horizons in at least a moderate amount, but the amount decreases with depth.

gates in the horizon. Clay skins lining the pores are scarce or absent, even though water can move rapidly through some of the larger pores. Weathered rock fragments that retain the original rock structure (saprolite) are absent or constitute less than 5 percent by volume unless they have been coated and cemented by iron oxides or gibbsite.

The presence of more than 5 percent by volume of saprolite within a depth of 2 m commonly marks the lower boundary of the oxic horizon. Pseudomorphs of olivine, mentioned earlier, may be present.

Color is not diagnostic. Some oxic horizons have varying shades of gray, brown, and red, or have mixtures of these colors in medium or coarse patterns of mottles.

The percentage of clay in different oxic horizons increases, decreases, or remains constant with depth. Horizons of different texture can have clear or abrupt boundaries if they are separated by a stone line. Otherwise, changes in the percentage of clay with depth are gradual or diffuse. If there are clay skins in pores and on peds somewhere within the soil, the relative increase in clay content [11] within a vertical distance of 30 cm (12 in.) is less than that required for the argillic horizon. Particularly, the oxic horizon does not have an abrupt or clear boundary with an overlying horizon that contains significantly less clay throughout its thickness. Such a boundary is one of the marks of an argillic horizon, and if it is present, one should look carefully for clay skins. Clay skins may be present only at a depth greater than 1 m if roots are scarce, but if they occupy more than 1 percent of the volume of any subhorizon, they indicate the presence of an argillic horizon.[12] Clay skins are present in some oxic horizons, but they should be very few and restricted mainly to the linings of pores. Pressure from swelling in some oxic horizons produces peds that have smooth, reflective faces. If the texture is fine, these faces resemble clay skins.

Summary of properties

In summary, the oxic horizon is a subsurface horizon, exclusive of the argillic or natric horizon, that

1. Is at least 30 cm thick;
2. Has a fine-earth fraction that retains 10 meq or less ammonium ions per 100 g clay from an unbuffered 1*N* NH_4Cl solution (meq of NH_4 retained per 100 g soil × 100 ÷ clay percentage [15] ≤ 10) or has <10 meq of bases extractable with NH_4OAc plus aluminum extractable with 1*N* KCl per 100 g clay;
3. Has an apparent cation-exchange capacity of the fine-earth fraction of 16 meq or less per 100 g clay by NH_4OAc unless there is an appreciable content of aluminum-interlayered chlorite (meq CEC per 100 g soil × 100 ÷ clay percentage ≤ 16, clay percentage as in footnote 15);
4. Does not have more than traces of primary aluminosilicates such as feldspars, micas, glass, and ferromagnesian minerals, as discussed earlier;

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[11] Clay measured by the pipette method.

[12] Clay skins commonly are abundant in saprolite below an oxic horizon, but their presence in the saprolite is not a mark of an argillic horizon.

[15] The percentage of clay as measured by the pipette method or 2.5 times 15-bar water, whichever value is higher but not more than 100.

5. Has texture of sandy loam or finer in the fine-earth fraction and has >15 percent clay;
6. Has mostly gradual or diffuse boundaries between its subhorizons; and
7. Has <5 percent by volume that shows rock structure.

Duripan

The duripan (L. *durus*, hard, plus pan; meaning hardpan) is a subsurface horizon that is cemented by silica to the degree that fragments from the air-dry horizon do not slake during prolonged soaking in water or in HCl.

Summary of properties

In summary, the duripan is a silica-cemented subsurface horizon in which
1. Cementation is strong enough that dry fragments from some subhorizon do not slake in water, even during prolonged wetting;
2. Coatings of silica, insoluble in 1*N* HCl even during prolonged soaking but soluble in hot concentrated KOH or in alternating acid and alkali, are present in some pores and on some structural faces; or some durinodes are present; and
3. Cementation is not destroyed by soaking in acid in more than half of any laminar capping that may be present or in some other continuous or imbricated subhorizon. Cementation in such layers is completely destroyed by hot concentrated KOH, either by a single treatment or by alternating with acid.
4. If fractured, the average lateral distance between fracture points is 10 cm or more.

Fragipan

A fragipan (modified from L. *fragilis*, brittle, and pan; meaning brittle pan) is a loamy or uncommonly a sandy subsurface horizon that may but does not necessarily underlie a cambic, spodic, argillic, or albic horizon. It has a very low content of organic matter, has high bulk density relative to the horizons above it, and is seemingly cemented when dry, having then hard or very hard consistence. When moist, a fragipan has moderate or weak brittleness, which is the tendency for a ped or clod to rupture suddenly when pressure is applied rather than to undergo slow deformation. A dry fragment slakes or fractures when placed in water. A fragipan is usually mottled, is slowly or very slowly permeable to water, and has few or many bleached, roughly vertical planes that are faces of coarse or very coarse polyhedrons or prisms.

Identification

There is no known laboratory procedure for identifying a sample of a fragipan. Identification is primarily a field problem. A combination of clues must be used because there is no single unique property of fragipans. First, position is important. A fragipan lies below an eluvial horizon unless the soil has been truncated, but it is not necessarily immediately below. If the soil has been truncated, the pan can be traced up slope until it lies under an eluvial horizon.

Second, if there is an argillic or a cambic horizon above a fragipan, there is commonly an A'2 horizon between the fragipan and the overlying horizon. The A′2 horizon is marked by uncoated grains of sand and silt. This horizon seems related to water that either stands above the pan or moves laterally along its surface.

Third, if the pan is not saturated for long periods, some or all pedons normally have bleached vertical streaks that form a roughly polygonal pattern on a horizontal plane. The bleached streaks are bounded by strong brown or reddish brown streaks where iron and manganese have accumulated (plate 6B). If the pan is saturated for long periods or if the texture is sandy, the polygonal color pattern may be absent.

Fourth, if the moisture content is near the wilting point, the matrix between the streaks is very firm. If it is near field capacity, the matrix is brittle. The brittle matrix should constitute 60 percent or more of the volume of some subhorizon.

Fifth, fine feeder roots are virtually absent in the brittle parts of a fragipan. If brittleness is so weakly expressed that fine feeder roots are present throughout the horizon, the horizon should not be considered a fragipan. It should be noted, however, that some trees have tap roots that extend through a well-expressed fragipan, but this is the exception rather than the rule. It is characteristic of fragipans that few or many roots may be present in the bleached vertical streaks and that few or no fine roots are present in the brittle matrix between the bleached streaks. The fine roots should not be present at intervals of <10 cm except within bleached vertical streaks, and the mean horizontal dimensions of the brittle matrix should be at least 10 cm.

Sixth, texture of the fine-earth fraction of a fragipan is finer than fine sand, and the percentage of clay is generally <35; in most soils appreciably less. The texture normally is loamy, that is, silt loam, loam, or sandy loam.

Seventh, an air-dry fragment about the size of a fist slakes or fractures when placed in water.

Albic horizon

The albic (L. *albus*, white) horizon is one from which clay and free iron oxides have been removed or in which the oxides have been segregated to the extent that the color of the horizon is determined by the color of the primary sand and silt particles rather than by coatings on these particles. An albic horizon may be at the surface of the mineral soil; it may lie just above an argillic or a spodic horizon; it may lie between a spodic horizon and either a fragipan or an argillic horizon; or it may lie between an argillic horizon and a fragipan or between a cambic horizon and an argillic horizon, natric horizon, or fragipan. It is usually underlain by a spodic, natric, or argillic horizon, a fragipan, or a relatively impervious layer that can produce a perched water table and either stagnant or moving water.

Deep deposits of pure white sand can be formed by wind or wave action. Although these deposits have the apparent morphology of an albic horizon, they are in fact a parent material. The white sand in such a deposit does not overlie a B horizon or any other soil horizon except, in some places, a buried soil.

An albic horizon, therefore, is defined as a surface or a lower horizon that has such thin or discontinuous coatings on the sand or silt particles that the hue and chroma of the horizon are determined chiefly by the color of the sand and silt particles.

The color value, moist, of an albic horizon is 4 or more, or the value, dry, is 5 or more, or both. If the value, dry, is 7 or more, or the value, moist, is 6 or more, the chroma is 3 or less. If the value, dry, is 5 or 6, or the value, moist, is 4 or 5, the chroma is closer to 2 than to 3. If parent materials have a hue of 5YR or redder, a chroma, moist, of 3 is permitted in the albic horizon if the chroma is due to the color of uncoated silt or sand grains. Under an albic horizon there is usually a B horizon that is an argillic or a spodic horizon, but in some few sandy soils the underlying horizon is too weakly developed to meet the levels of accumulation required for those horizons.

Calcic horizon and ca horizon

The calcic horizon is a horizon of accumulation of calcium carbonate or of calcium and magnesium carbonate. The accumulation may be in the C horizon, but it may also be in a variety of other horizons such as a mollic epipedon, an argillic or a natric horizon, or a duripan.

The calcic horizon has two forms. In one, the underlying materials have less carbonate than the calcic horizon. This form of calcic horizon includes horizons of secondary carbonate enrichment that are 15 cm (6 in.) or more thick, have a carbonate content equivalent to $\geq$15 percent $CaCO_3$, and have a $CaCO_3$ equivalent at least 5 percent greater than the C horizon. In the other form, the calcic horizon is 15 cm or more thick, has a $CaCO_3$ equivalent $\geq$15 percent, and contains $\geq$5 percent, by volume, of identifiable secondary carbonates as pendants on pebbles, concretions, or soft powdery forms. If this calcic horizon rests on limestone, marl, or other very highly calcareous materials ($\geq$40 percent $CaCO_3$ equivalent), the percentage of carbonates need not decrease with depth.

If the particle-size class is sandy, sandy-skeletal, coarse-loamy, or loamy-skeletal with less than 18 percent clay, the 15 percent requirement for $CaCO_3$ equivalent is waived. But to qualify as a calcic horizon, the horizon must have at least 5 percent (by volume) more soft powdery secondary $CaCO_3$ than an underlying horizon, and the calcic horizon must be at least 15 cm thick.

If a horizon enriched with secondary carbonate is indurated or cemented to the degree that dry fragments do not slake in water, it is considered to be a petrocalcic horizon, which is discussed later. Air-dry fragments of a calcic horizon will slake in water. Pendants below rocks and concretions normally do not slake, but these are not connected, and the soil material between the concretions will slake.

Gypsic horizon

The gypsic horizon is a noncemented or weakly cemented horizon of enrichment with secondary sulfates that is 15 cm or more thick, has at least 5 percent more gypsum than the C horizon or the underlying stratum, and in which the product of the thickness in centimeters and the percentage of gypsum is ≥ 150. Thus, a horizon 30 cm thick that has 5 percent gypsum qualifies if gypsum is absent in the underlying horizon. A layer 30 cm thick that has 6 percent gypsum qualifies if the gypsum content of the underlying horizon is not more than 1 percent. Cementation is weak enough that a dry fragment slakes in water.

The percentage of gypsum can be calculated by multiplying the milliequivalents of gypsum per 100 g soil by the milliequivalent weight of gypsum, which is 0.086.

Petrocalcic horizon

The petrocalcic horizon is a continuous, cemented or indurated calcic horizon that is cemented by calcium carbonate or in some places by calcium and some magnesium carbonate. Accessory silica may be present. The petrocalcic horizon is continuously cemented throughout the pedon to the degree that dry fragments do not slake in water. It cannot be penetrated by spade or auger when dry. It is massive or platy, very hard or extremely hard when dry, and very firm or extremely firm when moist. Noncapillary pores are filled, and the petrocalcic horizon is a barrier to roots. Hydraulic conductivity is moderately slow to very slow. The horizon is usually much more than 10 cm (4 in.) thick.

A laminar capping commonly is present but is not required.

If a laminar horizon rests on bedrock, it is considered a petrocalcic horizon if it is 2.5 cm or more thick and the product of the thickness in centimeters multiplied by the percentage of $CaCO_3$ equivalent is 200 or more.

Petrogypsic horizon

The petrogypsic horizon is a gypsic horizon that is strongly enough cemented with gypsum that dry fragments do not slake in water and that roots cannot enter. The gypsum content commonly is far greater than the minimum requirements for the gypsic horizon and usually exceeds 60 percent. Petrogypsic horizons are restricted to arid climates and to parent materials that are rich in gypsum.

Salic horizon

A salic horizon is a horizon 15 cm or more thick that contains a secondary enrichment of salts more soluble in cold water than gypsum. It contains at least 2 percent salt, and the product of its thickness in centimeters and salt percentage by weight is 60 or more. Thus, a horizon 20 cm thick would need to contain 3 percent salt to qualify as a salic horizon and a horizon 30 cm thick would need 2 percent.

Sulfuric horizon

The sulfuric (L. *sulfur*) horizon is composed either of mineral or organic soil material that has both a pH <3.5 (1:1 in water) and jarosite mottles (the color of fresh straw that has a hue of 2.5Y or yellower and chroma of 6 or more).

A sulfuric horizon forms as a result of artificial drainage and oxidation of sulfide-rich mineral or organic materials. Such a horizon is highly toxic to plants and virtually free of living roots.

Other diagnostic soil characteristics

Abrupt textural change

An abrupt textural change is a change from an ochric epipedon or an albic horizon to an argillic horizon. There is, in the zone of contact, a very appreciable increase in clay content within a very short distance in depth. If the clay content of the ochric epipedon or the albic horizon is <20 percent, the clay content should double within a distance in depth of 7.5 cm or less. If the clay content exceeds 20 percent, the increase in clay content should be at least 20 percent of the fine-earth fraction, for example, from 22 percent to 42 percent, within a distance of 7.5 cm in depth, and the clay content in some part of the argillic horizon should be at least double that of the horizon above.

A transitional horizon normally is not present or is too thin to be sampled. In some soils, however, there may be tonguing or interfingering of albic materials, which are defined later, in parts of the argillic horizon. The horizon boundary in such a soil is irregular or even discontinuous. The sampling of such a mixture as a single horizon might create the impression of a relatively thick transitional horizon, even though the thickness of the actual transition at the contact may be only 1 mm or so.

Amorphous material dominant in the exchange complex

Amorphous material, as the term is used here, is colloidal material that includes allophane and has all or most of the properties of allophane. The term is more inclusive, however, than allophane as it is defined by some workers. Amorphous material, as used here, is generally amorphous under X-ray analysis, but enough crystalline materials may be present, especially in mixtures, to cause small and disordered peaks. The amorphous material is associated with organic matter, but it contains aluminum, and it never has more than traces of aluminum that can be extracted with KCl. Consequently, if the base saturation is low, that is, <35 percent, the amorphous material has a permanent charge of less than 10 meq per 100 g. It has high exchange capacity, however, in a system buffered at pH 7, and very high exchange capacity at pH 8.2. The exchange capacity is clearly pH induced. The amorphous material also has high anion-exchange capacity. It has an enormous surface area and retains much water against 15-bar tension, commonly 50 to 100 percent or more. It cannot be dispersed readily in hexametaphosphate.

If amorphous material dominates an exchange complex, we find that the following conditions are satisfied:

1. The exchange capacity of the clay at pH 8.2 is >150 meq per 100 g measured clay, and commonly is >500 meq per 100 g. The high value is, in part, the result of the poor dispersion.

2. If there is enough clay to have a 15-bar water content of 20 percent or more, the pH of a suspension of 1 g soil in 50 ml 1*N* NaF is >9.4 after 2 minutes.
3. The ratio of 15-bar water content to measured clay is more than 1.0.
4. The amount of organic carbon exceeds 0.6 percent.
5. Differential thermal analysis shows a low-temperature endotherm.
6. The bulk density of the fine-earth fraction is <0.85 g per cubic centimeter at 1/3-bar tension.

Coefficient of linear extensibility, COLE

This coefficient is the ratio of the difference between the moist length and the dry length of a clod to its dry length. It is $(Lm - Ld) \div Ld$, where *Lm* is the length at 1/3-bar tension and *Ld* is the length when dry. It can be calculated from the difference in bulk density of the clod when moist and when dry. COLE can be estimated from shrinkage of a sample that has been packed at field capacity into a mold and then dried.

Durinodes

Durinodes (L. *durus*, hard; *nodus*, knot) are weakly cemented to indurated nodules. The cement is SiO_2, presumably opal and microcrystalline forms of silica. It breaks down in hot concentrated KOH after treatment with HCl to remove carbonates but does 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 and some slaking. The durinodes are firm or very firm; they are brittle when wet, both before and after treatment with acid; and they are disconnected and they range upward in size from a diameter of about 1 cm. Most durinodes are roughly concentric when viewed in cross section, and concentric stringers of opal may be visible under a hand lens.

Gilgai

Gilgai is the microrelief that is typical of clayey soils that have a high coefficient of expansion with changes in moisture content and that also have distinct seasonal changes in moisture content. The microrelief consists of either a succession of enclosed microbasins and microknolls in nearly level areas, which are illustrated in figure 4, or of microvalleys and microridges that run up and down the slope. The height of the microridges commonly ranges from a few centimeters to 1 m. Rarely does the height approach 2 m.

Lithic contact

A lithic contact is a boundary between soil and coherent underlying material. Except in Ruptic-Lithic subgroups the underlying material must be continuous within the limits of a pedon except for cracks produced in place without significant displacement of the pieces. Cracks should be few, and their average horizontal spacing should be 10 cm or more. The underlying material must be sufficiently coherent when moist to make hand digging with a spade impractical, although it may be chipped or scraped with a spade. If it is a single mineral, it must have a hardness by Moh's scale of 3 or more. If it is not a single mineral, chunks of gravel size that can be broken out must not disperse during shaking for 15 hours in water or in sodium hexametaphosphate solution. 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 50 cm of the surface of a mineral soil.

Mottles that have chroma of 2 or less

It refers to colors in a horizon in which parts have chroma of 2 or less, moist, and value, moist, of 4 or more, whether or not that part is dominant in volume or whether or not it is a continuous phase surrounding spots of higher chroma. If either the minor or major part of a horizon has chroma of 1 to 2 and value, moist, of 4 or more and there are spots of higher chroma, the part that has the lower chroma is included in the meaning of "mottles that have chroma of 2 or less." The part is excluded from the meaning if all the horizon has chroma of 2 or less or if no part of the horizon has chroma as low as 2.

The phrase also means that the horizon that has such mottles is saturated with water at some period of the year or the soil is artificially drained. It is also implicit in the meaning that the temperature of the horizon is above the biologic zero, which is about 5° C (41° F), during at least a part of the time that the horizon is saturated.

n value

The *n* value (Pons and Zonneveld 1965) refers to the relation between the percentage of water under field conditions and the percentages of inorganic clay and of humus. The *n* value is helpful in predicting whether the soil may be grazed by livestock or will support other loads and the degree of subsidence that would occur after drainage. The *n* value can be calculated for mineral soil materials that are not thixotropic by the formula:

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

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 (organic carbon x 1.724).

Few data are available in the United States for calculations of the *n* value, but the critical *n* value of 0.7 can be approximated closely in the field by a simple test of squeezing the soil in the hand. If the soil flows with difficulty between the fingers, the *n* value is between 0.7 and 1.0. If the soil flows easily between the fingers, the *n* value is 1 or more.

Organic soil materials

Organic soil materials either

1. Are saturated with water for long periods or are artificially drained, and have 18 percent or more organic carbon if the mineral fraction is 60 percent or more clay, 12 percent or more organic carbon if the

mineral fraction has no clay, or a proportional amount of organic carbon between 12 and 18 percent if the clay content is between zero and 60 percent; or

2. Are never saturated with water for more than a few days and have 20 percent or more organic carbon.

Item 1 in this definition covers materials that have been called peat and muck. Item 2 is intended to include materials that have been called "litter" or O horizons. Not all organic soil materials accumulate under water. Leaf litter may rest on a lithic contact and yet may support a forest. The only "soil" in this situation is organic in the sense that the mineral fraction may be appreciably less than half the weight and only a small proportion of the volume of the soil.

Paralithic contact

A paralithic (lithiclike) contact is a boundary between soil and continuous coherent underlying material. It differs from a lithic contact in that the underlying material, if a single mineral, has a hardness by Moh's scale of <3. If the underlying material is not a single mineral, chunks of gravel size that can be broken out disperse more or less completely during 15 hours of end-over-end shaking in water or in sodium hexametaphosphate solution and, when moist, the material can be dug with difficulty with a spade.

Permafrost

Permafrost is a layer in which the temperature is perennially at or below 0° C, whether the consistence is very hard or loose. Dry permafrost has loose consistence. Plate 8A shows a soil that has permafrost within about 30 cm of the surface.

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 absent or is present only in traces (fig. 5). The indurated layer must be continuous within the limits of a pedon but may be fractured if the average lateral distance between fractures is ≥ 10 cm. The indurated layer is distinguished from a placic horizon and from an indurated spodic horizon (ortstein) because it contains little or no organic matter. Organic matter is present in both the other horizons.

Several features can aid in making the distinction between a lithic and a petroferric contact. First, a petroferric contact is roughly horizontal. Second, the amount of iron in the material immediately below a petroferric contact is high. The content of Fe_2O_3 normally ranges upward from 30 percent. Third, the ironstone sheets below a petroferric contact are thin. Their thickness ranges from a few centimeters to a very few meters. Sandstone, on the other hand, may be thin or very thick, may be level bedded or tilted, and may have only a small percentage of Fe_2O_3. In the Tropics the ironstone commonly is more or less vesicular.

Plinthite

Plinthite (Gr. *plinthos*, brick) is an iron-rich, humus-poor mixture of clay with quartz and other diluents. It commonly occurs as dark red mottles, which usually are in 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 exposed also to heat from the sun. The lower boundary of a zone in which plinthite occurs usually is diffuse or gradual, but it may be abrupt at a lithologic discontinuity.

Generally, plinthite forms in a horizon that is saturated with water at some season. The original segregation of the iron normally is in the form of soft, more or less clayey, red or dark red mottles. The mottles are not considered plinthite unless there has been enough segregation of iron to permit irreversible hardening on exposure to wetting and drying. Plinthite in the soil usually 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 does not harden irreversibly as a result of a single cycle of drying and rewetting. After a single drying, it will remoisten, and then it can be dispersed in large part by shaking in water with a dispersing agent.

In a moist soil, plinthite is soft enough that it can 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 by shaking in water with a dispersing agent.

Potential linear extensibility

This characteristic is the sum of the products, for each horizon, of the thickness of the horizon in centimeters and the COLE of the horizon.

Sequum: number and kind

A sequence of an eluvial horizon and its subjacent B horizon, if one is present, is called a sequum. An albic horizon and a spodic horizon immediately underlying it, for example, constitute a sequum. Similarly, a mollic epipedon over a cambic horizon or an argillic horizon over a ca horizon also constitute a sequum. Two sequa may be present in vertical sequence in a single soil, and that sequence is called a bisequum.

Slickensides

Slickensides are polished and grooved surfaces that are produced by one mass sliding past another. Some of them occur at the base of a slip surface where a mass of soil moves downward on a relatively steep slope. Slickensides are very common in swelling clays in which there are marked changes in moisture content. Plate 7C is a photograph of such a slickenside.

Soft powdery lime

Soft powdery lime is a phrase that is used in the definitions of a number of taxa. It refers to translocated authigenic lime, soft enough to be cut readily with a fingernail, that was precipitated in place from the soil solution rather than inherited from a soil parent material such as a calcareous loess or till. It should be present in a significant enough accumulation to constitute a ca horizon.

To be identifiable, soft powdery lime must have some relation to the soil structure or fabric. It may disrupt the fabric to form spheroidal aggregates, or white eyes, that are soft and powdery when dry. Or the lime may be present as soft coatings in pores or on structural faces. If present as coatings, it covers a significant part of the surface. Commonly, it coats the whole surface to a thickness of 1 to 5 mm or more. But only part of a surface may be coated if little lime is present in the soil. The coatings should be thick enough to be visible when moist and should cover a continuous area large enough to be more than filaments. The pseudomycelia commonly seen in a dry calcareous horizon do not come within the meaning of soft powdery lime. Pseudomycelia are soft powdery filaments on structural faces, commonly branching, but they may come and go with the seasons and may be only lime that was precipitated in a single season by the withdrawal of stored soil moisture rather than a ca horizon.

Soft coatings on hard lime concretions are also excluded from the meaning of soft powdery lime. These may be thin or thick, and they may be the result of either current accumulation or removal of lime. That is, the concretion may be growing or may be undergoing dissolution, and either process can produce a soft coating.

Soil moisture regimes

The soil moisture regime, as the term is used here, refers to the presence or absence either of ground water or of water held at a tension <15 bars in the soil or in specific horizons by periods of the year. Water held at a tension of 15 bars or more is not available to keep most mesophytic plants alive. The availability of water also is affected by dissolved salts. A soil may be saturated with water that is too salty to be available to most plants, but it would seem better to call such a soil salty rather than dry. Consequently, we consider a horizon to be dry when the moisture tension is 15 bars or more. If water is held at a tension of <15 bars but more than zero, we consider the horizon to be moist. A soil may be continuously moist in some or all horizons throughout the year or for some part of the year. It may be moist in winter and dry in summer or the reverse. In the northern hemisphere, summer refers to the months of June, July, and August, and winter means December, January, and February. A soil or a horizon is considered to be saturated with water when water stands in an unlined borehole close enough to the soil surface or to the horizon* in question that the capillary fringe [17] reaches the surface or the top of the horizon.

[17] The capillary fringe is the zone just above the water table (zero gauge pressure) that remains almost saturated (Soil Sci Soc. Amer. Glossary, 1965, p. 332).

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 >15 bars but not air dry) soil will be moistened by 2.5 cm (1 in.) of water within 24 hours. The lower boundary is the depth to which a dry soil will be moistened by 7.5 cm (3 in.) of water within 48 hours. These depths are exclusive of 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 lithic, petroferric, or paralithic contact or to a petrocalcic horizon or a duripan, the upper boundary of the rock or of the cemented horizon is the lower boundary of the soil moisture control section. If 2.5 cm of water moistens the soil to one of these contacts or horizons, the soil moisture control section is the lithic contact itself, the paralithic contact. or the upper boundary of the cemented horizon. The control section of the latter soil is moist if the upper boundary of the rock or the cemented horizon has a thin film of water. If the upper boundary is dry, the control section is dry.

As a rough guide to the limits, the soil moisture control section lies approximately between 10 and 30 cm (4 and 12 in.) if the particle-size class is fine-loamy, coarse-silty, fine-silty, or clayey. The control section extends approximately from a depth of 20 cm to a depth of 60 cm (8 to 24 in.) if the particle-size class is coarse-loamy, and from 30 to 90 cm (12 to 35 in.) if the particle-size class is sandy.

Classes of soil moisture regimes

The moisture regimes are defined in terms of the ground-water level and in terms of the presence or absence of water held at a tension <15 bars in the moisture control section by periods of the year. It is assumed in the definitions that the soil supports whatever vegetation it is capable of supporting. In other words, it is in crops, grass, or native vegetation; it is not being fallowed to increase the amount of stored moisture, nor is it being irrigated by man. These cultural practices affect the soil moisture condition as long as they are continued.

Aquic moisture regime.—The aquic (L. *aqua,* water) moisture regime implies a reducing regime that is virtually free of dissolved oxygen because the soil is saturated by ground water or by water of the capillary fringe. An aquic regime must be a reducing one. Some soil horizons, at times, are saturated with water while dissolved oxygen is present, either because the water is moving or because the environment is unfavorable for micro-organisms, for example, if the temperature is < 1° C such a regime is not considered aquic.

For differentiation in the highest categories of soils that have an aquic regime, the whole soil must be saturated. In the subgroups, only the lower horizons are saturated. The soil is considered to be saturated if water stands in an unlined borehole at such a shallow depth that the capillary fringe (see footnote 17) reaches the soil surface except in noncapillary pores. The water in the borehole is stagnant and remains colored if a dye is placed in the water. In a sandy soil, the thickness of the capillary fringe may be only 10 to

15 cm. In a loamy or clayey soil that does not shrink or swell appreciably, the thickness may be 30 cm or more, depending on the size distribution of the pores.

The duration of the period that the soil must be saturated to have an aquic regime is not known. 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 (5° C) at some time while the soil or the horizon is saturated.

Very commonly, the level of ground water fluctuates with the seasons. The level 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. A tidal marsh and a closed, landlocked depression fed by perennial streams are examples. The moisture regime in these soils is called "peraquic." Although the term is not used as a formative element for names of taxa, it is used in their descriptions as an aid in understanding genesis.

Aridic and torric (L. *aridus*, dry, and L. *torridus*,[18] hot and dry) moisture regimes.—These terms are used for the same moisture regime but in different categories of the taxonomy.

In the aridic (torric) moisture regime, the moisture control section in most years is

1. Dry in all parts more than half the time (cumulative) that the soil temperature at a depth of 50 cm is above 5° C; and
2. Never moist in some or all parts for as long as 90 consecutive days when the soil temperature at a depth of 50 cm is above 8° C.

Soils that have an aridic or a torric moisture regime are normally in arid climates. A few are in semiarid climates and either have physical properties that keep them dry, such as a crusty surface that virtually precludes infiltration of water, or they are very shallow over bedrock. There is little or no leaching in these moisture regimes, and soluble salts accumulate in the soil if there is a source of them.

The limits of soil temperature exclude from these moisture regimes the very cold and dry regions of Greenland and adjacent islands. Such fragmentary data are available on the soils of those regions that no provision is made for their moisture regimes in this taxonomy.

Udic moisture regime.—The udic (L. *udus*, humid) moisture regime implies that in most years the soil moisture control section is not dry in any part for as long as 90 days (cumulative). 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 differ by 5° C or more, the soil moisture control section is not dry in all parts for as long as 45 consecutive days in the 4 months that follow the summer solstice in 6 or more years out of 10. In addition, the udic moisture regime requires, except for short pe-

[18] *Torridus* is not the ideal root, but a better one could not be found. Although soils may not be hot throughout the year, soils that have a torric moisture regime are hot and dry in summer.

riods, a three-phase system, solid-liquid-gas, in part, but not necessarily in all, of the soil when the soil temperature is above 5° C.

The udic moisture regime is common to the soils of humid climates that have well-distributed rainfall or that have enough rain in summer that the amount of stored moisture plus rainfall is approximately equal to or exceeds the amount of evapotranspiration. Water moves down through the soil at some time in most years.

If precipitation exceeds evapotranspiration in all months of most years, there are occasional brief periods when some stored moisture is used, but the moisture tension rarely becomes as great as 1 bar in the soil moisture control section. The water moves through the soil in all months that it is not frozen. This extremely wet moisture regime is called "perudic" (L. *per*, throughout in time, L. *udus*, moist). The formative element *ud* is used in the names of most taxa to indicate either a udic or a perudic regime. The term "perudic" is not used in names of taxa, but is used in the text if it is relevant to the genesis of the soils.

Ustic moisture regime.—The ustic (L. *ustus*, burnt, implying dryness) moisture regime is intermediate between the aridic and the udic regime. The concept is one of limited moisture, but the moisture is present at a time when conditions are suitable for plant growth. The ustic moisture regime is not applied to soils that have cryic or pergelic temperature regimes, which are defined later.

If the mean annual soil temperature is 22° C or higher or if the mean summer and winter soil temperatures differ by $<5°$ C at a depth of 50 cm, the soil moisture control section in the ustic moisture regime is dry in some or all parts for 90 or more cumulative days in most years. But the moisture control section is moist in some part for more than 180 cumulative days, or it is continuously moist in some part for at least 90 consecutive days.

If the mean annual soil temperature is lower than 22° C and if the mean summer and winter soil temperatures differ by 5° C or more at a depth of 50 cm, the soil moisture control section in the ustic regime is dry in some or all parts for 90 or more cumulative days in most years. But it is not dry in all parts for more than half the time that the soil temperature is higher than 5° C at a depth of 50 cm (the aridic and torric regimes). Also, it is not dry in all parts for as long as 45 consecutive days in the 4 months that follow the summer solstice in 6 or more years out of 10 if the moisture control section is moist in all parts for 45 or more consecutive days in the 4 months that follow the winter solstice in 6 or more years out of 10 (xeric regime).

In tropical and subtropical regions that have either one or two dry seasons, summer and winter have little meaning. In those regions, the ustic regime is that typified in a monsoon climate that has 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 they have a dormant period while the soil is dry.

Xeric moisture regime.—The xeric moisture regime (Gr. *xeros*, dry) is that typified in Mediterranean climates, where winters are moist and cool and summers are warm and dry. The moisture, coming in winter when potential evapotranspiration is at a minimum, is particularly effective for leaching. In a xeric moisture regime, the soil moisture control section is dry in all parts for 45 or more consecutive days within the 4 months that follow the summer solstice in 6 or more years out of 10. It is moist in all parts for 45 or more consecutive days within the 4 months that follow the winter solstice in 6 or more years out of 10. The moisture control section is moist in some part more than half the time, cumulative, that the soil temperature at a depth of 50 cm is higher than 5° C, or in 6 or more years out of 10 it is moist in some part for at least 90 consecutive days when the soil temperature at a depth of 50 cm is continuously higher than 8° C. In addition, the mean annual soil temperature is lower than 22° C, and mean summer and mean winter soil temperatures differ by 5° C or more at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower. Figure 13 gives climatic data that typify the xeric

Soil temperature regimes

Classes of soil temperature regimes

The following soil temperature regimes are used in defining classes at various categoric levels in the taxonomy.

Pergelic (L. *per*, throughout in time and space, and L. *gelare*, to freeze; connoting permanent frost).—Soils with a pergelic temperature regime have mean annual temperature lower than 0° C. These are soils that have permafrost if they are moist or dry frost if excess water is not present. It seems likely that the moist and the dry pergelic regimes should be defined separately, but at present we have only fragmentary data on the dry soils of very high latitudes.

Cryic (Gr. *kryos*, coldness; connoting very cold soils).—In this regime soils have a mean annual temperature higher than 0° C (32° F) but lower than 8° C (47° F).

1. In mineral soils, the mean summer temperature for June, July, and August at a depth of 50 cm or at a 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) There is no O horizon, lower than 15° C (59° F);
      (2) There is an O horizon, lower than 8° C (47° F);
   b. If the soil is saturated with water during some part of the summer and
      (1) There is no O horizon, lower than 13° C (55° F);
      (2) There is an O horizon or a histic epipedon, lower than 6° C (43° F).
2. In organic soils, either
   a. The soil is frozen in some layer within the control section in most years about 2 months after the summer solstice; that is, the soil is very cold

in winter but warms up slightly in summer; or
b. The soil is not frozen in most years below a depth of 5 cm; that is, the soil is cold throughout the year but, because of marine influence, does not freeze in most years.

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

Most isofrigid soils with a mean annual soil temperature above 0° C have a cryic temperature regime. A few with organic materials in the upper part are exceptions. Throughout this text all isofrigid soils without permafrost are considered to have a cryic temperature regime.

Frigid.—The frigid regime and some of the others that follow are used chiefly in defining classes of soils in the low categories. In the frigid regime the soil is warmer in summer than one in the cryic regime, but its mean annual temperature is lower than 8° C (47° F), and the difference between mean winter and mean summer soil temperature is more than 5° C (9° F) at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower.

Mesic.—The mean annual soil temperature is 8° C or higher but lower than 15° C (59° F), and the difference between mean summer and mean winter soil temperature is more than 5° C at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower.

Thermic.—The mean annual soil temperature is 15° C (59° F) or higher but lower than 22° C (72° F), and the difference between mean summer and mean winter soil temperature is more than 5° C at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower.

Hyperthermic.—The mean annual soil temperature is 22° C (72° F) or higher, and the difference between mean summer and mean winter soil temperature is more than 5° C at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower.

If the name of a soil temperature regime has the prefix iso, the mean summer and winter soil temperatures for June, July, and August and for December, January, and February differ by less than 5° C at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower.

Isofrigid.—The mean annual soil temperature is lower than 8° C (47° F).

Isomesic.—The mean annual soil temperature is 8° C or higher but lower than 15° C (59° F).

Isothermic.—The mean annual soil temperature is 15° C or higher but lower than 22° C (72° F).

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

The limit between isofrigid and isomesic cannot be tested in the United States and is tentative.

Sulfidic materials

Sulfidic materials are waterlogged mineral or organic soil materials that contain 0.75 percent or more sulfur (dry weight), mostly in the form of sulfides and that have less than three times as much carbonate ($CaCO_3$ equivalent) as sulfur. Sulfidic materials accumulate in a soil that is permanently saturated, generally with brackish water. The sulfates in the water are biologically reduced to sulfides as the soil materials accumulate. Sulfidic materials are most common in coastal marshes near the mouths of rivers that carry noncalcareous sediments, but they may occur in fresh-water marshes if there is sulfur in the water. If the soil is drained, the sulfides oxidize and form sulfuric acid. The pH, which normally is near neutrality before drainage, may drop below 2. The acid reacts with the soil to form iron and aluminum sulfates. The iron sulfate, jarosite, segregates and forms the bright-yellow mottles that characterize a sulfuric horizon. The transition from sulfidic materials to a sulfuric horizon normally requires a very few years. A sample of sulfidic materials, if air dried slowly in shade for about 2 months with occasional remoistening, becomes extremely acid. For quick identification in the field, a sample can be oxidized by boiling in concentrated H_2O_2 and measuring the drop in pH.[19]

Thixotropy

Thixotropy is "a reversible gel-sol transformation under isothermal shearing stress following rest" (Webster's 1967). The term means "to change by touch." Many kinds of thixotropic substances have been identified and studied, including some sesquioxide gels, kaolinite gels, montmorillonite gels, greases, inks, paints, protoplasm, blood coagula, nitrocellulose solutions, and drilling muds. Thixotropy apparently is the result of a kind of structure that, if broken down, can rebuild itself. The breakdown may be caused by one of several actions: by agitation, by shearing, or even by ultrasonic waves. Some natural (untreated) soil materials exhibit this property. A field test of thixotropic soil is this: Press a bit of wet soil between thumb and forefinger; at first it resists deformation, having some rigidity, or elasticity, or both; under increasing pressure the soil can be molded and deformed; under greater pressure, suddenly the soil changes from a plastic solid to a liquid, and the fingers skid. After the soil smears in this fashion, usually free water can be seen on the fingers. In a matter of a second or two the liquefied soil sets again to its original solid state. If a knife blade is pushed into the soil mass in a pit and removed suddenly, it has only a staining of muddy water; if pressed into the soil and slowly pulled out, a large mass of soil adheres to the blade. In the literature of soils of western United States, particularly of Hawaii, the consistence term "smeary" is used to characterize soil materials that are thixotropic.

Tonguing and interfingering

Tonguing of albic materials

Tongues of albic materials consist of penetrations of bleached material that has the color of an albic horizon in an argillic or a natric horizon, along ped surfaces if peds are present. No continuous albic horizon need be present above the tongues. The penetrations have a vertical dimension of >5 cm in any argillic or natric horizon. Their horizontal dimension is 5 mm or

[19] Concentrated H_2O_2 can cause serious burns and is dangerous. Gloves should be worn, and precautions should be taken against spilling, leakage, or spattering.

more in a fine-textured argillic or natric horizon (clay, silty clay, or sandy clay), 10 mm or more in a moderately fine textured argillic or natric horizon (clay loam, sandy clay loam, or silty clay loam), and 15 mm or more in a medium or coarser textured argillic or natric horizon (silt loam, loam, very fine sandy loam, or coarser). The penetrations must occupy more than 15 percent of the matrix of some part of the argillic or natric horizon before they are considered tongues.

Interfingering of albic materials

Interfingering of albic materials consists of penetrations of albic materials into an underlying argillic or natric horizon along faces of peds, primarily along vertical faces but to a lesser degree along horizontal faces. No continuous albic horizon need be present. The penetrations are not wide enough to constitute tonguing, but they form continuous skeletans (ped coatings of clean silt or sand defined by Brewer, 1964) >1 mm thick on the vertical ped faces, which means a total width >2 mm between abutting peds. Because quartz is such a common constituent of soils, the skeletans usually appear to be nearly white when dry and light gray when moist, but their color is determined in large part by the color of the sand or silt fraction.

To be recognized as interfingering, all the following requirements must be met in a horizon that is 5 cm or more thick:

1. Half or more of the matrix consists of peds of the argillic or natric horizon;
2. Albic materials are thicker than 2 mm on vertical faces between abutting peds but are too thin to be tongues;
3. Clay skins are present in the peds, at least in pores.

Albic materials meet the following requirements for color. If the value, dry, is 7 or more, or the value, moist, is 6 or more, the chroma is 3 or less. If the value, dry, is 5 or 6 and the value, moist, is 4 or 5, the chroma is closer to 2 than to 3.

Weatherable minerals

Several references are made to weatherable minerals in the text of this chapter and later chapters. Obviously, the stability of a mineral in a soil is a partial function of the soil moisture regime. In the context of the references in the definitions of diagnostic horizons and of various taxa, a humid climate is always assumed, either present or past. Minerals that are included in the meaning of weatherable minerals are:

1. Clay minerals: All 2:1 lattice clays except one that is currently considered to be an aluminum-interlayered chlorite. Sepiolite, talc, and glauconite are also included in the meaning of this group of weatherable clay minerals, although they are not everywhere of clay size.
2. Silt- and sand-size minerals (0.02 to 0.2 mm in diameter): Feldspars, feldspathoids, ferromagnesian minerals, glass, micas, zeolites, and apatite.

It should be noted that this is a restricted meaning of weatherable minerals. Calcite, for example, is readily soluble in a humid environment. If it is dissolved, it leaves no trace or residue. Soils that have been intensely and deeply weathered in a humid environment of the past are, in some places, preserved today in an arid environment. Calcite could reappear in one of these soils if it were brought in as dust. The intent is to include, in the context of the meaning of weatherable minerals for this purpose, only those minerals that are unstable in a humid climate relative to other minerals, such as quartz and 1:1 lattice clays, and that are more resistant to weathering than calcite.

Horizons and Properties Diagnostic for the Higher Categories: Organic Soils

Organic soil materials

Organic soil materials and organic soils

1. Are saturated with water for long periods or are artificially drained and, excluding live roots, (a) have 18 percent or more organic carbon if the mineral fraction is 60 percent or more clay, (b) have 12 percent or more organic carbon if the mineral fraction has no clay, or (c) have a proportional content of organic carbon between 12 and 18 percent if the clay content of the mineral fraction is between zero and 60 percent; or
2. Are never saturated with water for more than a few days and have 20 percent or more organic carbon.

Definition of organic soils

Organic soils (Histosols) are soils that

1. Have organic soil materials that extend from the surface to one of the following:
   a. A depth within 10 cm or less of a lithic or paralithic contact, provided the thickness of the organic soil materials is more than twice that of the mineral soil above the contact; or
   b. Any depth if the organic soil material rests on fragmental material (gravel, stones, cobbles) and the interstices are filled with organic materials, or rests on a lithic or paralithic contact; or
2. Have organic materials that have an upper boundary within 40 cm of the surface and
   a. Have one of the following thicknesses:
      (1) 60 cm or more if three-fourths or more of the volume is moss fibers or the moist bulk density is <0.1 g per cubic centimeter (6.25 lbs per cubic foot);
      (2) 40 cm or more if
         (a) The organic soil material is saturated with water for long periods (>6 months) or is artificially drained; and
         (b) The organic material consists of sapric or hemic materials or consists of fibric materials that are less than three-fourths moss fibers by volume and have a moist bulk density of 0.1 or more; and
   b. Have organic soil materials that
      (1) Do not have a mineral layer as much as 40 cm thick either at the surface or whose upper boundary is within a depth of 40 cm from the surface; and
      (2) Do not have mineral layers, taken cumulatively, as thick as 40 cm within the upper 80 cm.

It is a general rule that a soil is classed as an organic soil (Histosol) either if more than half of the upper 80 cm (32 in.) of soil is organic or if organic soil material of any thickness rests on rock or on fragmental material having interstices filled with organic materials.

Kinds of organic soil materials

Three basic kinds of organic soil materials are distinguished, fibric, hemic, and sapric, according to the degree of decomposition of the original plant materials.

Fibers

A fiber is a fragment or piece of plant tissue, excluding live roots, that is large enough to be retained on a 100-mesh sieve (openings 0.15 mm in diameter) and that retains recognizable cellular structure of the plant from which it came. The material is screened after dispersion in sodium hexametaphosphate. Fragments larger than 2 cm in cross section or in their smallest dimension, to be called fibers, must be decomposed enough that they can be crushed and shredded with the fingers. Fragments of wood that are larger than 2 cm in cross section and that are so undecomposed that they cannot be crushed and shredded with the fingers are not considered fibers.

Fibric soil materials (L. *fibra*, fiber)

Fibric soil materials have the following characteristics:

1. The fiber content after rubbing is three-fourths [2] or more of the soil volume, excluding coarse fragments and mineral layers; or
2. The fiber content after rubbing is two-fifths or more of the soil volume, excluding coarse fragments and mineral layers, and the material yields a sodium pyrophosphate extract color on white chromatographic paper that has value and chroma of 7/1, 7/2, 8/1, 8/2, or 8/3

Hemic soil materials

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

Sapric soil materials (Gr. *sapros*, rotten)

These are the most highly decomposed of the organic materials. They normally have the smallest amount of plant fiber, the highest bulk density, and the lowest water content on a dry-weight basis at saturation. They 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 the others.

Sapric materials have the following characteristics:

1. The fiber content after rubbing is less than one-sixth of the soil volume, excluding coarse fragments and mineral layers; and
2. The sodium pyrophosphate extract color on chromatographic paper is below or to the right of a line drawn to exclude blocks 5/1, 6/2, and 7/3 on the chart.

Humilluvic materials

Illuvial humus accumulates in the lower parts of some organic soils if they are acid and have been drained and cultivated. The illuvial humus has a younger ^{14}C age 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 illuvial humus should constitute at least half the volume of a layer at least 2 cm thick.

Limnic materials

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 coprogenous earth (sedimentary peat) layer is a limnic layer that

1. Contains many fecal pellets a few hundredths to a few tenths of a millimeter in diameter;
2. Has a color value, moist, <5;
3. Either forms a slightly viscous water suspension and is slightly plastic but not sticky or shrinks upon drying to form clods that are difficult to rewet and that often tend to crack along horizontal planes;
4. Is normally but not necessarily nearly devoid of fragments of plants that can be recognized with the eye; and
5. Yields a saturated sodium pyrophosphate extract on white filter paper that has higher color value and lower chroma than 10 YR 7/3 (fig. 24) or the cation-exchange capacity is <240 meq per 100 g of organic matter (measured by loss on ignition) or both.

Diatomaceous earth

A diatomaceous earth layer is a limnic layer that

1. Has a matrix color value of 3 through 5 if not previously dried, and the value changes irreversibly on drying. The color change results from irreversible shrinkage of organic matter coatings on diatoms, which can be identified by microscopic (440 X) examination of dry samples; and
2. Yields a color higher in value and lower in chroma than 10 YR 7/3 (fig. 24) on white filter paper that is inserted into a paste made of the material in a saturated sodium pyrophosphate solution or the cation-exchange capacity is <240 meq per 100 g of organic matter (by loss on ignition) or both.

Marl

A marl layer is a limnic layer that

1. Has a color value, moist, of 5 or more; and
2. Reacts with dilute HCl to evolve CO_2 and leave disintegrated plant remains.

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

Thickness of organic materials (control section)

For practical reasons an arbitrary control section has been established for taxonomy of Histosols. It is either 130 cm (51 in.) or 160 cm (63 in.) thick, depending on the kind of material, provided that no lithic or paralithic contact, thick layer of water, or frozen soil occurs within those limits. The thicker control section is used if the surface layer to a depth of 60 cm (24 in.) has three-fourths or more fibers derived from *Sphagnum* or from *Hypnum* or other mosses or has a bulk density <0.1. Layers of water may be thin or thick, from a few centimeters to many meters. Water is taken as the base of the control section only if the water extends below a depth of 130 cm or 160 cm, depending on the kind of material above it. A lithic or a paralithic contact shallower than 130 cm (51 in.) or 160 cm (63 in.), depending on the kind of material above it, is taken as the base of the control section, or the base is placed 25 cm (10 in.) below the depth at which the soil is frozen about 2 months after the summer solstice. An unconsolidated mineral substratum shallower than those limits does not change the base of the control section.

The control section has been divided somewhat arbitrarily into three tiers, the surface, subsurface, and bottom tiers.

Surface tier

The surface tier is the upper 60 cm (24 in.) if (1) the material is fibric and three-fourths or more of the fiber volume is derived from *Sphagnum* or mosses or (2) the material has a bulk density <0.1; otherwise, the surface tier is the top 30 cm (12 in.) exclusive of loose surface litter or living mosses.

A surface mineral layer <40 cm (16 in.) thick is present on some organic soils as a result of flooding, additions by men to increase soil strength or reduce frost hazard, volcanic eruptions, or other causes. If present, it is considered a part of the surface tier, even though it may be >30 cm thick, and the depth then is measured from the top of the mineral layer.

Subsurface tier

The subsurface tier is 60 cm (24 in.) thick unless the control section ends at a lithic or paralithic contact or at water within this depth or unless the soil is frozen at too shallow a depth. In any of these situations the subsurface tier extends from the base of the surface tier to the base 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 (16 in.) thick unless the control section stops within the maximum span.

Family differentiae for mineral soils

The differentiae used to distinguish families of mineral soils within a subgroup are listed next in the order in which the descriptive terms appear in the family name and in which the terms are defined in this chapter.

Particle-size classes
Mineralogy classes
Calcareous and reaction classes
Soil temperature classes
Soil depth classes
Soil slope classes
Soil consistence classes
Classes of coatings (on sands)
Classes of cracks

Particle-size classes

Particle size refers to grain-size distribution of the whole soil and is not the same as texture, which refers to the fine-earth fraction. The fine-earth fraction consists of the particles that have a diameter <2 mm. Particle-size classes are a kind of compromise between engineering and pedologic classifications. The limit between sand and silt is a diameter of 74 microns in the engineering classification and of either 50 or 20 microns in pedologic classifications. The engineering classifications are based on percentages by weight in the fraction <74 mm in diameter, and textural classes are based on percentages by weight in the fraction <2 mm in diameter.

The very fine sand separate (diameter between 0.05 mm and 0.1 mm) is split in engineering classifications. In defining particle-size classes, much the same split is made but in a different manner. A fine sand or loamy fine sand normally has an appreciable content of very fine sand, but the very fine sand fraction is mostly coarser than 74 microns. A silty sediment, such as loess, may also have an appreciable component of very fine sand, but most of the very fine sand is finer than 74 microns. So, in particle-size classes, the very fine sand is allowed to "float." It is treated as sand if the texture is fine sand, loamy fine sand, or a coarser class. It is treated as silt if the texture is very fine sand, loamy very fine sand, sandy loam, silt loam, or a finer class.

No single set of particle-size classes seems appropriate as family differentiae for all kinds of soils. The classes that follow provide for a choice of either 7 or 11 particle-size classes. This choice permits relatively fine distinctions in soils if the particle size is important and broader groupings if the particle size is not susceptible to precise measurement or if the use of narrowly defined classes produces undesirable groupings. Thus in some families the term "clayey" indicates that there is 35 percent or more clay in defined horizons, but in other families the term "fine" indicates that the clay fraction constitutes 35 through 59 percent of the fine earth of the horizons, and the term "very-fine" indicates 60 percent or more clay. The term "rock fragments" refers to particles 2 mm in diameter or larger and includes all sizes that have horizontal dimensions less than the size of a pedon. It is not the same as coarse fragments, which excludes stones and boulders larger than about 25 cm. The term "fine earth" refers to particles smaller than 2 mm in diameter.

Definitions of classes

Fragmental.—Stones, cobbles, gravel, and very coarse sand particles; too little fine earth to fill interstices larger than 1 mm in diameter.

Sandy-skeletal.—Rock fragments 2 mm in diameter or larger make up 35 percent or more by volume; enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is sandy as defined for the sandy particle-size class.

Loamy-skeletal.—Rock fragments make up 35 percent or more by volume; enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is loamy as defined for the loamy particle-size class.

Clayey-skeletal.—Rock fragments make up 35 percent or more by volume; enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is clayey as defined for the clayey particle-size class.

Sandy.—The texture of the fine earth is sand or loamy sand but not loamy very fine sand or very fine sand; rock fragments make up <35 percent by volume.

Loamy.[1]—The texture of the fine earth is loamy very fine sand, very fine sand, or finer, but the amount of clay is <35 percent; rock fragments are <35 percent by volume.

Coarse-loamy. By weight, 15 percent or more of the particles are fine sand (diameter 0.25–0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; <18 percent clay in the fine-earth fraction.

Fine-loamy. By weight, 15 percent or more of the particles are fine sand (diameter 0.25–0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; 18 through 34 percent clay in the fine-earth fraction (<30 percent in Vertisols).

Coarse-silty. By weight, <15 percent of the particles are fine sand (diameter 0.25–0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; <18 percent clay in the fine-earth fraction.

Fine-silty. By weight, <15 percent of the particles are fine sand (diameter 0.25–0.1 mm) or coarser, including fragments up to 7.5 cm in diameter; 18 through 34 percent clay in the fine-earth fraction (<30 percent in Vertisols).

Clayey.[1]—The fine earth contains 35 percent or more clay by weight, and rock fragments are <35 percent by volume.

Fine. A clayey particle-size class that has 35 through 59 percent clay in the fine-earth fraction (30 through 59 percent in Vertisols).

Very-fine. A clayey particle-size class that has 60 percent or more clay in the fine-earth fraction.

Modifiers that replace names of particle-size classes

There are three situations in which particle-size class names are not used. In one, the name is redundant. Psamments and Psammaquents, by definition, are sandy, and no particle-size class name is needed or used in the family name.

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[1] If the ratio of 15-bar water to clay is 0.6 or more in half or more of the control section, the percentage of clay is considered to be 2.5 times the percentage of 15-bar water. Carbonates of clay size are not considered to be clay but are treated as silt in all particle-size classes.

In the second situation, particle size is a meaningless concept because, presumably, the soil consists of a mixture of discrete mineral particles and of gels. The concept of either texture or particle size is not applicable to a gel, particularly if the gel cannot be dispersed. Consequently, no particle-size class names are used if the soil is mostly glass or if the exchange complex is dominated by amorphous materials, as is the situation with Andepts by definition. In families of Andepts and Andaquepts, in most andic subgroups of Inceptisols and andaqueptic and andeptic subgroups of other orders, and in families of Entisols and Aridisols with modifiers listed below, particle-size class names, as such, are not used for the part of the soil that does not disperse.

In the third situation, the content of organic matter is high and particle size has only limited relation to the physical and chemical properties of the soils. This seems to be normal in soils that have both a cryic temperature regime and a spodic horizon. Therefore, particle-size class names are not used for the spodic horizons [2] of Cryaquods, Cryohumods, Cryorthods, or Cryic Placohumods.

The following terms are substituted for the particle-size class names in the taxa that have been listed unless the particle-size modifier is redundant. They reflect a combination of particle size and mineralogy, and they take the place of both.

Cindery.—Sixty percent or more of the whole soil (by weight) [3] volcanic ash, cinders, and pumice; 35 percent or more (by volume) is cinders that have diameter of 2 mm or more.

Ashy and ashy-skeletal.—These are mainly soils that have a fine-earth fraction that feels like a sand or a loamy sand after prolonged rubbing.

Ashy. Sixty percent or more of the whole soil (by weight) volcanic ash, cinders, and pumice; <35 percent (by volume) is 2 mm in diameter or larger.

Ashy-skeletal. Rock fragments other than cinders are 35 percent or more (by volume); the fine-earth fraction is otherwise ashy.

Medial and medial-skeletal.—These are soils that have a fine-earth fraction that feels loamy, as the term is defined earlier in this chapter, after prolonged rubbing.

Medial. Less than 60 percent of the whole soil (by weight) volcanic ash, cinders, and pumice; <35 percent (by volume) is 2 mm in diameter or larger; the fine-earth fraction is not thixotropic; the exchange complex is dominated by amorphous materials.

Medial-skeletal. Thirty-five percent (by volume) or more rock fragments other than cinders 2 mm in diameter or larger; the fine-earth fraction is otherwise medial.

Thixotropic and thixotropic-skeletal.—These are soils that have a fine-earth fraction that is thixotropic

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[2] Particle-size class names are applied to other spodic horizons but with reservations. Somewhat different classes probably should be used for most families of Spodosols, but data are too few to permit the testing of alternatives. Some series that would otherwise be reasonably homogeneous are split at the family level by the particle-size classes. These soils have appreciable but not very large amounts of organic matter in the spodic horizon.

[3] Percentages by weight in these definitions are estimated from grain counts; usually, a count of one or two dominant size fractions of the conventional mechanical analysis is enough for placement of the soil.

and an exchange complex dominated by amorphous clays.

Thixotropic. Less than 35 percent (by volume) has diameter of 2 mm or larger; the fine-earth fraction is thixotropic; the exchange complex is dominated by amorphous materials.

Thixotropic-skeletal. Thirty-five percent or more (by volume) rock fragments other than cinders 2 mm in diameter or larger; the fine-earth fraction is thixotropic.

Control section for particle-size classes or their substitutes

Names of particle-size classes or their substitutes as defined are not applied to a fragipan, duripan, or a petrocalcic horizon but are applied to specific horizons or to the materials between given limits of depth that are defined in terms of either the distance below the surface of the mineral soil or the upper boundary of a specified horizon. The vertical section so defined is called the control section. Definitions of the control section for determination of the particle-size classes are arranged as a key.

A. Particle-size modifiers or substitutes are used to describe material from the surface to a lithic or paralithic contact; or to a fragipan, duripan, or petrocalcic horizon if any of these come within a depth of 36 cm (14 in.) or less; or to a depth of 36 cm if the soil temperature is 0° C or lower within this depth about 2 months after the summer solstice.

B. In other soils that do not have an argillic horizon or a natric horizon and in great groups of Spodosols, Alfisols, and Ultisols that have a spodic horizon or a fragipan in or above an argillic horizon:

1. Particle-size modifiers or substitutes are used to describe material from the base of the Ap horizon or from a depth of 25 cm, whichever is greater, to a lithic or paralithic contact, fragipan, duripan, or petrocalcic horizon if the depth to any of these is <1 m; or to a depth 25 cm below the level at which the soil temperature is 0° C about 2 months after the summer solstice; whichever is shallower.
2. Otherwise, particle-size modifiers or substitutes are used to describe material from a depth of 25 cm to a depth of 1 m.

C. In other soils of the orders Alfisols and Ultisols and in great groups of Aridisols and Mollisols that have an argillic horizon that has (a) a lower boundary deeper than 25 cm (see E) and (b) an upper boundary shallower than 1 m, or the soil is in a grossarenic subgroup:

1. If there are no strongly contrasting particle-size classes, as defined later, and there is no fragipan, duripan, or petrocalcic horizon between the top of the argillic or natric horizon and a depth of 1 m, particle-size modifiers or substitutes are used to describe the whole argillic or natric horizon if it is <50 cm thick[4] or the upper 50 cm of the argillic or natric horizon if it is >50 cm thick.
2. If there are horizons or layers of strongly contrasting particle-size classes, as defined later, within or below the argillic or natric horizon and within a depth of 1 m, particle-size modifiers or substitutes are used to describe material from the top of the argillic or natric horizon to a depth of 1 m or to a lithic or paralithic

[4] The upper boundary of the argillic horizon is not always obvious. If properties of an argillic horizon are present but the upper boundary is gradual, use the depth at which the percentage of clay exceeds that of a higher lying horizon by the appropriate amount after fitting to a smooth curve. If the boundary is irregular or broken, as in A&B or B&A horizons, use the depth at which half or more of the volume has the fabric of an argillic horizon.

contact, duripan, fragipan, or petrocalcic horizon, whichever is shallower.

3. If there is a fragipan, duripan, or petrocalcic horizon below an argillic or natric horizon, particle-size modifiers or substitutes are used to describe material from the top of the argillic horizon, excluding any part incorporated in an Ap horizon, to the top of the fragipan, duripan, or petrocalcic horizon, or are used to describe the upper 50 cm of the argillic or natric horizon whichever of these is less.

D. In other soils in the orders Alfisols and Ultisols and in great groups of Aridisols and Mollisols that have an argillic or natric horizon that has its upper boundary at a depth >1 m and that are not in a grossarenic subgroup, particle-size modifiers or substitutes are applied to describe material from a depth of 25 cm to a depth of 1 m below the mineral surface.

E. In other soils in which the lower boundary of the argillic or natric horizon is shallower than 25 cm, that is, they have a *ca* horizon in which there is soft powdery lime, or have a calcic or other named diagnostic horizon that has its upper boundary within 25 cm of the surface, or have rock structure dominant within that depth, particle-size classes are used to describe material from the top of the argillic horizon or the base of an Ap horizon, whichever is shallower, to a lithic or paralithic contact, a petrocalcic or petrogypsic horizon, duripan, or to a depth of 1 m, whichever is shallowest.

Strongly contrasting particle-size classes

In applying names of particle-size classes, the weighted average particle-size class of the control section or of the horizons listed is named unless there are strongly contrasting particle-size classes within the control section or the horizons. If there are strongly contrasting particle-size classes, both particle-size classes are named. Thus, if the weighted average of the upper part of the control section is loamy fine sand and the lower part is clay, the family differentia is sandy over clayey. If there are more than two contrasting particle-size classes within the control section, the classes differing most in median particle size are named. Sandy includes fine sand as well as coarser sands. Medial, ashy, or thixotropic substitutes are applied only if the materials extend at least 10 cm into the upper part of the control section.

The following particle-size classes are strongly contrasting if the transition between them is less than 12.5 cm thick:

1. Cindery over sandy or sandy-skeletal.
2. Cindery over loamy.
3. Sandy-skeletal over loamy if the loamy material has <50 percent fine or coarser sand.
4. Sandy over loamy if the loamy material has <50 percent fine or coarser sand.
5. Sandy over clayey.
6. Ashy over cindery.
7. Ashy over loamy-skeletal.
8. Ashy over loamy.
9. Loamy-skeletal over fragmental.
10. Loamy-skeletal over sandy.
11. Loamy-skeletal over clayey if there is an absolute difference of >25 percent in the percentages of clay in the fine earth fractions.
12. Clayey-skeletal over sandy.
13. Medial over fragmental.
14. Medial over cindery.
15. Medial over sandy or sandy-skeletal.
16. Medial over loamy-skeletal.
17. Medial over loamy.

18. Medial over clayey.
19. Medial over thixotropic.
20. Coarse-loamy over fragmental.
21. Coarse-loamy over sandy or sandy-skeletal if the coarse-loamy material has <50 percent fine or coarser sand.
22. Loamy over sandy or sandy-skeletal if the loamy material has <50 percent fine or coarser sand.
23. Coarse-loamy over clayey.
24. Coarse-silty over sandy or sandy-skeletal.
25. Coarse-silty over clayey.
26. Fine-loamy over fragmental.
27. Fine-loamy over sandy or sandy-skeletal.
28. Fine-loamy over clayey if there is an absolute difference of >25 percent in the percentage of clay.
29. Fine-silty over fragmental.
30. Fine-silty over sandy or sandy-skeletal.
31. Fine-silty over clayey if there is an absolute difference of >25 percent in the percentages of clay.
32. Clayey over fragmental.
33. Clayey over sandy or sandy-skeletal.
34. Clayey over loamy-skeletal if there is an absolute difference of >25 percent in the percentages of clay in the fine-earth fraction.
35. Clayey over loamy if there is an absolute difference of >25 percent in the percentages of clay.
36. Clayey over fine-silty if there is an absolute difference of >25 percent in the percentages of clay.
37. Thixotropic over fragmental.
38. Thixotropic over sandy or sandy-skeletal.
39. Thixotropic over loamy-skeletal.
40. Thixotropic over loamy.

The intent in setting up classes of strongly contrasting particle sizes is to identify changes in pore-size distribution that seriously affect movement and retention of water and that have not been identified in higher categories. The list given is intended for use in grouping the soil series of the United States into families. It is not intended as a complete list. For example, fine sand over coarse sand is common in the Udipsamments of western Europe but is not known to be important in the United States.

Choice of 7 or 11 particle-size classes

Only the. seven particle-size classes are used in lithic, arenic, and grossarenic subgroups and in shallow families.

In families of Ultisols and Oxisols not included in the preceding item, subclasses of loamy particle-size classes are used but not subclasses of the clayey classes.

If only a part of the control section of a soil in an andic or andeptic subgroup or other group where substitute terms are used is cindery, ashy, medial, or thixotropic, contrasting families are recognized, but only the seven particle-size classes are used. For example, we might use cindery over loamy but not cindery over fine-loamy.

Only two particle-size classes are used to separate families in Vertisols, fine if there is <60 percent clay and very-fine if there is 60 percent or more clay in the weighted average of the control section.

Mineralogy classes

The control section

Mineralogy classes are based on the approximate mineralogical composition of selected size fractions of the same segment of the soil (control section) that is used for application of particle-size classes.

Contrasting mineralogy modifiers

Contrasting mineralogy modifiers are not recognized except where substitutes for particle-size class modifiers have been used. In those soils there is an overlay of ash or cinders, or an upper medial or thixotropic layer, and the ashy, cindery, medial, or thixotropic layer extends at least 10 cm into the upper part of the control section. In identifying and naming the contrasting mineralogy modifiers in families of those soils, the seven particle-size classes are used to describe the lower part of the section. For example, a pair of contrasting layers is named as medial over loamy, mixed, not medial over coarse-loamy, mixed.

If there are layers of contrasting particle size in the control section, the mineralogy class of the upper part of the control section is definitive of the family mineralogy. For example, if there is fine-loamy material of mixed mineralogy over sandy material that is siliceous, the proper modifiers to describe the family are fine-loamy over sandy, mixed, not fine-loamy, mixed, over sandy, siliceous.

Key to mineralogy classes

Mineral soils are placed in the first mineralogy class of the key (table 12) that accommodates them although they may appear also to meet the requirements of other mineralogy classes. This is a key, not a set of complete definitions. Substitute terms connoting both particle size and mineralogy are based on combined texture, consistence, and mineralogy classes and are used to indicate important variations in Andaquepts, Andepts, andic, andaqueptic, and andeptic subgroups, in cryic great groups and cryic subgroups of Spodosols, and in cindery and ashy families of Aridisols and Entisols. Mineralogy classes are not named in Calciaquolls because the effect of the carbonates overshadows other differences in mineralogy, and they are not named in Quartzipsamments, which, by definition, are siliceous.

It is recognized that it is normally impossible to be certain of the percentages of the various kinds of clay minerals. Quantitative methods of identification are still subject to change. Although much progress has been made in the past few decades, an element of judgment enters into the estimation. All the evidence does not need to come from X-ray, surface, and DTA determinations. Other physical and chemical properties suggest the mineralogy of many clayey soils. Changes in volume, cation-exchange capacity, and consistence are useful in estimating the nature of clay.

The description of clay mineralogy in naming families of clayey soils is based on the weighted average of the control section.

Class	Definition	Determinant size fraction
CLASSES APPLIED TO SOILS OF ANY PARTICLE-SIZE CLASS		
Carbonatic	More than 40 percent by weight carbonates (expressed as $CaCO_3$) plus gypsum, and the carbonates are >65 percent of the sum of carbonates and gypsum.	Whole soil, particles <2 mm in diameter or whole soil <20 mm, whichever has higher percentage of carbonates plus gypsum.
Ferritic	More than 40 percent by weight iron oxide extractable by citrate-dithionite, reported as Fe_2O_3 (or 28 percent reported as Fe).	Whole soil, particles <2 mm in diameter.
Gibbsitic	More than 40 percent by weight hydrated aluminum oxides, reported as gibbsite and bohemite.	Whole soil, particles <2 mm in diameter.
Oxidic	Less than 90 percent quartz; <40 percent any other single mineral listed subsequently; and the ratio, percent extractable iron oxide plus percent gibbsite to percent clay,[1] is 0.20 or more. That is, $\frac{\text{extractable } Fe_2O_3\text{(pct.)} + \text{gibbsite(pct.)}}{\text{clay(pct.)}^1} \geq 0.2$	For quartz and other minerals, fraction 0.02 to 2 mm in diameter; for ratio of iron oxide and gibbsite to clay, whole soil <2 mm.
Serpentinitic	More than 40 percent by weight serpentine minerals (antigorite, chrysotile, fibrolite, and talc).	Whole soil, particles <2mm in diameter.
Gypsic	More than 40 percent by weight of carbonates (expressed as $CaCO_3$) plus gysum, and the gypsum is >35 percent of the sum of carbonates and gypsum.	Whole soil, particles <2 mm in diameter, or whole soil <20 mm, whichever has higher percentage of carbonates plus gypsum.
Glauconitic	More than 40 percent glauconite by weight.	Whole soil, particles <2 mm in diameter.

[1] Percentage of clay or percentage of 15-bar water times 2.5, whichever is greater, provided the ratio of 15-bar water to clay is 0.6 or more in half or more of the control section.

Class	Definition	Determinant size fraction
CLASSES APPLIED TO SOILS THAT HAVE A FRAGMENTAL, SANDY, SANDY-SKELETAL, LOAMY, OR LOAMY-SKELETAL PARTICLE-SIZE CLASS		
Micaceous	More than 40 percent mica by weight.[2]	0.02 to 20 mm.
Siliceous	More than 90 percent by weight[2] of silica minerals (quartz, chalcedony, or opal) and other extremely durable minerals that are resistant to weathering. See weatherable minerals (ch. 3).	0.02 to 2 mm.
Mixed	All others that have <40 percent of any one mineral other than quartz or feldspars.	0.02 to 2 mm.

[2] Percentages by weight are estimated from grain counts. Usually, a count of one or two of the dominant size fractions of a conventional mechanical analysis is sufficient for placement of the soil.

Class	Definition	Determinant size fraction
CLASSES APPLIED TO SOILS THAT HAVE A CLAYEY OR CLAYEY-SKELETAL PARTICLE-SIZE CLASS		
Halloysitic	More than half halloysite[3] by weight and smaller amounts of allophane or kaolinite or both.	<0.002 mm.
Kaolinitic	More than half kaolinite, tabular halloysite, dickite, and nacrite by weight, smaller amounts of other 1:1 or nonexpanding 2:1 layer minerals or gibbsite, and <10 percent montmorillonite.	<0.002 mm.
Montmorillonitic	More than half montmorillonite and nontronite by weight or a mixture that has more montmorillonite than any other one clay mineral.	<0.002 mm.
Illitic	More than half illite (hydrous mica) by weight and commonly >4 percent K_2O.	<0.002 mm.
Vermiculitic	More than half vermiculite by weight or more vermiculite than any other one clay mineral.	<0.002 mm.
Chloritic	More than half chlorite by weight or more chlorite than any other clay mineral.	<0.002 mm.
Mixed	Other soils.[4]	<0.002 mm.

[3] Halloysite as used here includes only the tubular forms. What has been called tabular halloysite is grouped here with kaolinite.
[4] Sepiolitic, defined as containing more than half by weight of sepiolite, attapulgite, and palygorskite, should be named if found.

Calcareous and reaction classes

The presence or absence of carbonates and the reaction are treated together because they are so intimately related. A calcareous horizon cannot be strongly acid. Calcareous classes are applied to the section between a depth of 25 and 50 cm or between a depth of 25 cm and a lithic or paralithic contact that is below a depth of 25 but not 50 cm, or to some part of the soil above a lithic or paralithic contact that is shallower than 25 cm. Two classes, calcareous and noncalcareous, are used in selected taxa. The definitions follow.

Calcareous.—The fine-earth fraction effervesces in all parts with cold dilute HCl.

Noncalcareous.—The fine-earth fraction does not effervesce in all parts with cold dilute HCl. The term noncalcareous is not used as a part of a family name.

It should be noted that a soil that contains dolomite is calcareous and that effervescence of dolomite, when treated with cold dilute HCl, is slow.

Reaction classes are applied to the control section that is defined for particle-size classes. Two classes, acid and nonacid, are used in selected taxa. The definitions follow.

Acid.—The pH is <5.0 in 0.01 M $CaCl_2$ (2:1) throughout the control section (about 5.5 in H_2O, 1:1).

Nonacid.—The pH is 5.0 or more in 0.01 M $CaCl_2$ (2:1) in at least some part of the control section. The term nonacid is not used in the family name of calcareous soils.

Reaction classes are used only in names of families of Entisols and Aquepts; they are not used in sandy, sandy-skeletal, and fragmental families of these taxa, nor are they used in Sulfaquepts and Fragiaquepts, or in families that have carbonatic or gypsic mineralogy.

Calcareous classes are used if appropriate in the same taxa as reaction classes and, in addition, are used in families of Aquolls except for Calciaquolls and for Aquolls that have an argillic horizon. Calcareous and reaction classes are not used in soils that have carbonatic or gypsic mineralogy. A soil that is calcareous is never acid. Calcareous therefore implies nonacid, and both names are not used because nonacid would be redundant. Similarly, noncalcareous would be redundant in acid families, and it is not used as part of the family name. If calcareous is used in a family name, calcareous is considered to be a subclass of mineralogy. It follows the mineralogy class name and is shown in parenthesis, for example: fine-loamy, mixed (calcareous), mesic Typic Haplaquolls.

Soil temperature classes

Soil temperature classes, as named and defined here, are used as family differentiae in all orders. The names are used as family modifiers unless the name of a higher taxon carries the same limitation. Thus, frigid is implied in all boric suborders and cryic great groups, and is redundant if used in the name of a family.

The Celsius (centigrade) scale is the standard. Approximate Fahrenheit equivalents are indicated parenthetically. It is assumed that the temperature is that of a soil that is not being irrigated.

For soils in which the difference is 5° C (9° F) or more between mean summer (June, July, and August in the northern hemisphere) and mean winter (December, January, and February in the northern hemisphere) soil temperature at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower, the classes, defined in terms of the mean annual soil temperature, are as follows:

Frigid.—Below 8° C (47° F).

Mesic.—From 8° to 15° C (47° to 59° F).

Thermic.—From 15° to 22° C (59° to 72° F).

Hyperthermic.—22° C (72° F) or higher.

For soils in which the difference is less than 5° C (9° F) between mean summer and mean winter soil temperature at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower, the classes, defined in terms of the mean annual soil temperature, are as follows:

Isofrigid.—Below 8° C (47° F).

Isomesic.—From 8° to 15° C (47° to 59° F).

Isothermic.—From 15° to 22° C (59° to 72° F).

Isohyperthermic.—22° C (72° F) or higher.

The appropriate limit between isofrigid and isomesic cannot be tested in the United States and probably will need to be revised.

Other characteristics

Several soil characteristics other than those already mentioned are needed in particular taxa to provide reasonable groupings of series into families. Some of these seem to be logical family criteria. Others probably should have been used in higher categories, but the lack of information about them makes it much safer to use them as family differentiae at this time. These characteristics include depth of soil, consistence, moisture equivalent, slope of soil, and permanent cracks.

Depth of soil

Classes of shallow and deep soils may be needed at the family level in all the orders of mineral soils. Some distinctions in depth are made in great groups and in arenic, paralithic, and lithic subgroups, but some other soils should also be grouped in families according to depth. Some soils have a paralithic contact over soft rock such as clay shale that is too compact for penetration by roots. The soil depth classes follow:

Micro.—Less than 18 cm through diagnostic horizons. Used in cryic great groups but not in pergelic subgroups or in Entisols.

Shallow.—Two depths are considered shallow.

a. Less than 50 cm to the upper boundary of a duripan or a petrocalcic horizon or to a paralithic or a petroferric contact. Used in all great groups of Entisols, Inceptisols, Aridisols, Mollisols, Spodosols, Alfisols, and Ultisols, except pergelic subgroups of the cryic great groups (Cryaquepts, Cryumbrepts, Cryorthods, and so on). Note that lithic subgroups are also shallow, but the adjective "shallow" in a family name of them is redundant.

b. Less than 1 m to a lithic or paralithic or a petroferric contact. Used in families of Oxisols.

Consistence

Some cemented horizons, for example, a duripan, are differentiae in the classification in categories above the family. Others such as a cemented spodic horizon (ortstein) are not, but no single family should include soils that have a continuous, shallow, cemented horizon and soils that do not. In Spodosols, in particular, a cemented spodic horizon needs to be used as a family differentia. The following classes of consistence are defined for Spodosols.

Ortstein.—All or part of the spodic horizon is at least weakly cemented, when moist, into a massive horizon that is present in more than half of each pedon.

Noncemented.—The spodic horizon, when moist, is not cemented into a massive horizon in as much as half of each pedon.

Cementation of a small volume into shot or concretions does not constitute cementation to form a massive horizon. The name of a family of noncemented Spodosols normally does not have a modifier to imply lack of cementation. The name of a family of cemented Spodosols contains the modifier "ortstein."

A cemented calcic or gypsic horizon is not identified in the family name. Many calcic and some gypsic horizons are weakly cemented and some are indurated. The recognition of a petrocalcic or petrogypsic horizon is expected to meet most, if not all, the needs for recognition of cementation in those horizons. Taxa of these cemented soils are not named in the family category.

Classes of coatings (on sands)

Despite the emphasis given to particle-size classes in the taxonomy, variability remains in the sandy particle-size class, which takes in sands and loamy sands. Some sands are very clean, almost completely free of silt and clay. Others are mixed with appreciable amounts of finer grains. A moisture equivalent of 2 percent makes a reasonable division of the sands at the family level. Two classes of Quartzipsamments are defined in terms of their moisture equivalent.

Coated.—The moisture equivalent is 2 percent or more.

Uncoated.—The moisture equivalent is <2 percent. The moisture retained at tension of 0.5 bar may be substituted for the moisture equivalent. Or, if moisture tension data are not available, the silt plus clay is ≤ 5 percent.

The moisture equivalent for this distinction is the weighted average for the control section, weighted for the thickness of each horizon or layer.

Slope or shape of soil

Soils of aquic great groups normally have level or concave surfaces. They are mainly in places where ground water saturates the soil during some period of the year. A few, however, are on the sides of slopes where water cannot stand and are kept wet by more or less continuous precipitation and by seepage of water from higher areas. In a very few, the hydrostatic pressure keeps the soil wet. No consistent internal morphologic clues have yet been found that distinguish these sloping aquic soils if the dissolved oxygen content is low, but their recognition in the field from the position of the soil in the landscape is generally easy. It is proposed, therefore, in aquic great groups, particularly in Aquolls and Aquults, to use the shape of the soil as a family differentia. Classes of level and sloping soils seem adequate, as these classes are defined in the Soil Survey Manual (Soil Survey Staff 1951). It may be necessary to use slope classes as family differentiae in other orders, but they should not be used in families of Aquods or Albaqualfs. Level is assumed in families of aquic soils if no slope modifier is used in the family name.

Classes of permanent cracks

Hydraquents consolidate[5] after drainage and become Fluvaquents. In the process, they form polyhedrons, roughly 12 to 50 cm in diameter, depending on the *n*-value and particle size. The polyhedrons are separated by cracks that range in width from 2 mm to >1 cm. The polyhedrons may shrink and swell with changes in moisture content of the soil, but the cracks are permanent and can persist for some hundreds of years even though the soils are cultivated. The cracks permit rapid movement of water through the soil either vertically or laterally. Yet the soils may have the same particle size, mineralogy, and other family properties as soils that are not cracked or that have cracks that open and close with the seasons. The soils that have permanent cracks are so rare in the United States that only a provisional definition of their characteristics can be presented.

The modifier "cracked" is used only to designate families of Fluvaquents. It means that there are continuous, permanent, lateral and vertical cracks, at least 2 mm wide, spaced at average lateral intervals of 50 cm or less. If this modifier is not in the family name, permanent cracks are assumed to be absent.

Family differentiae for Histosols

Most of the differentiae used to distinguish families of Histosols have been defined earlier, either because they are differentiae in mineral soils as well as in Histosols or because their definitions are essential for the classification of some Histosols in categories higher than the family. The differentiae that are not defined elsewhere are defined in this section and the taxa in which they are used are enumerated.

The order in which family modifiers are placed in the technical family names of Histosols follows. The modifiers chosen are those appropriate to the particular family.

Particle size
Mineralogy, including nature of limnic deposits
Reaction
Soil temperature regime
Soil depth

The differentiae are discussed in the remainder of this section.

[5] The process is designated by a Dutch word that means "to ripen" because the change resembles the change in consistence of cheese as water is removed.

Particle-size classes

Particle-size modifiers are used in family names of Histosols only in terric subgroups. The terms used follow.

Fragmental
Loamy-skeletal or clayey-skeletal
Sandy or sandy-skeletal
Loamy
Clayey

The meaning of each of these terms is the same as that defined for particle-size classes of mineral soils. The proper term is selected to describe the weighted average particle size of the upper 30 cm of the mineral layer or that part of the mineral layer that is within the control section, whichever is thicker.

Minerology classes

Mineralogy classes of Histosols are of three kinds, according to the nature of the subgroup or great group.

Ferrihumic.—Containing ferrihumic materials within the control section (applied to Fibrists, Hemists, and Saprists, except Sphagnofibrists and sphagnic subgroups of other great groups). Bog iron is present in some Histosols or in organic soil materials. It is called ferrihumic material. It consists of authigenic deposits (formed in place) of hydrated iron oxides mixed with varying kinds or amounts of organic materials. The iron in some places is present in large cemented aggregates. In others it may be mostly dispersed and soft. The colors normally are shades of dark reddish brown, commonly mixed with black, and the colors change little on drying. The content of iron oxide ranges from 10 percent to >20 percent.

Ferrihumic material either is saturated with water for long periods (>6 months) or is in an artificially drained soil. The content of free iron oxide should exceed 10 percent (7 percent Fe), but the horizon may be either organic or mineral provided there is at least 1 percent organic matter. The materials should have >2 percent (by weight) concretions of iron, which may range in size from fine (<5 mm) to 1 m or more in the largest lateral dimension. Colors should be dark reddish brown or reddish brown, or should be close to those colors. The presence of ferrihumic material within the control section is one of the family differentiae.

If ferrihumic is used as a modifier in the technical family name, no other mineralogy modifier is used because the presence of the iron is considered to be, by far, the most important characteristic.

Modifiers applied only to terric subgroups.—The mineralogy modifiers used for mineral soils are applied to the mineral parts of the soil for which a particle-size modifier has been used if the mineralogy is not ferrihumic.

Modifiers applied to limnic subgroups.—If limnic materials are present in the control section, if they are 5 cm or more thick, and if the materials do not have ferrihumic mineralogy, the following modifiers are used.

Coprogenous. Limnic materials that consist of coprogenous earth are present.

Diatomaceous. Limnic materials that consist of diatomaceous earth are present.

Marly. Limnic materials that consist of marl are present.

Reaction classes

Modifiers to indicate reaction are used in all subgroups. The meanings follow.

Euic.—The pH of undried samples is 4.5 or more (0.01 M $CaCl_2$) in at least some part of the organic materials in the control section.

Dysic.—The pH is <4.5 (in 0.01 M $CaCl_2$) in all parts of the organic materials in the control section.

Soil temperature classes

Names and definitions of classes follow the rules given for soil temperature classes of mineral soils. Frigid, however, is redundant in boric and cryic great groups and is not used. No temperature modifier is used in pergelic subgroups.

Soil depth classes

Soil depth modifiers are used in all lithic subgroups of Histosols except in the suborder of Folists. It is assumed that lithic Folists have a shallow lithic contact. Other lithic Histosols have a lithic contact within the control section but it may be as much as 160 cm deep.

Shallow families.—Used in lithic subgroups to indicate a lithic contact between a depth of 18 cm and 50 cm.

Micro families.—Used to indicate a lithic contact shallower than 18 cm without regard to soil temperature. (In mineral soils, micro families are restricted to cryic great groups.)

Identification of the Taxonomic Class of a Soil

Key to soil orders

In this key and the other keys that follow, the diagnostic horizons and the properties mentioned do not include the properties of buried soils except their organic carbon if of Holocene age and base saturation. Properties of buried soils are considered in the categories of subgroups, families, and series but not in those of order, suborder, and great group. The meaning of the term "buried soil" is given in chapter 1.

A. Soils that
 1. Have organic soil materials that extend from the surface to one of the following:
  a. A depth within 10 cm or less of a lithic or paralithic contact, provided the thickness of the organic soil materials is more than twice that of the mineral soil above the contact; or
  b. Any depth if the organic soil material rests on fragmental material (gravel, stones, cobbles) and the interstices are filled with organic materials, or rests on a lithic or paralithic contact; or
 2. Have organic materials that have an upper boundary within 40 cm of the surface and
  a. Have one of the following thicknesses:
   (1) 60 cm or more if three-fourths or more of the volume is moss fibers or the moist bulk density is <0.1 g per cubic centimeter (6.25 lbs per cubic foot);
   (2) 40 cm or more if
    (a) The organic soil material is saturated with water for long periods (>6 months) or is artificially drained; and
    (b) The organic material consists of sapric or hemic materials or consists of fibric materials that are less than three-fourths moss fibers by volume and have a moist bulk density of 0.1 or more; and
  b. Have organic soil materials that
   (1) Do not have a mineral layer as much as 40 cm thick either at the surface or whose upper boundary is within a depth of 40 cm from the surface; and
   (2) Do not have mineral layers, taken cumulatively, as thick as 40 cm within the upper 80 cm.

Histosols, p. 211 *70*

B. Other soils that do not have a plaggen epipedon but that have
 1. A spodic horizon whose upper boundary is within 2 m of the surface; or
 2. A placic horizon that meets all the requirements of a spodic horizon except thickness and index of accumulation and rests on a fragipan, on a spodic horizon, or on an albic horizon that rests on a fragipan.

Spodosols, p. 333 *82*

C. Other soils that
 1. Have an aquic moisture regime and have plinthite that forms a continuous phase within 30 cm of the surface of the mineral soil; or
 2. Have an oxic horizon within 2 m of the soil surface but do not have a plaggen epipedon and do not have either an argillic or a natric horizon that overlies the oxic horizon.[1]

Oxisols, p. 323 *80*

D. Other soils that have a mean annual soil temperature of 8° C or higher and
 1. Do not have a lithic or paralithic contact, petrocalcic horizon, or duripan within 50 cm of the surface; and

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[1] If an epipedon is more than 2 m thick but is immediately underlain by an oxic horizon, the soil is included with Oxisols.

2. After the soil to a depth of 18 cm has been mixed, as by plowing, have 30 percent or more clay in all subhorizons to a depth of 50 cm or more; and
3. Have, at some time in most years unless irrigated or cultivated, open cracks [2] at a depth of 50 cm that are at least 1 cm wide and extend upward to the surface or to the base of the plow layer or surface crust; and
4. Have one or more of the following;
   a. Gilgai;
   b. At some depth between 25 cm and 1 m, slickensides close enough to intersect; or
   c. At some depth between 25 cm and 1 m, wedge-shaped natural structural aggregates that have their long axes tilted 10° to 60° from the horizontal.

Vertisols, p. 375 *87*

E. Other soils that have an ochric or anthropic epipedon and either
1. Do not have an argillic or a natric horizon but
   a. Are saturated with water within 1 m of the surface for 1 month or more in some years and have a salic horizon whose upper boundary is within 75 cm of the surface; or
   b. Have one or more of the following horizons whose upper boundary is within 1 m of the soil surface: a petrocalcic, calcic, gypsic, petrogypsic, or cambic horizon or a duripan; and either
      (1) Have an aridic moisture regime, or
      (2) Have an ustic or a xeric moisture regime and a conductivity of the saturation extract at 25° C that is 2 mmho per centimeter or more in some subhorizon that is shallower than the least of the following:
         (a) A lithic or paralithic contact, petrocalcic horizon, or duripan at a depth of <25 cm;
         (b) 1.25 m if the weighted average particle-size class is sandy or sandy-skeletal between a depth of 25 cm and 1 m or between a depth of 25 cm and a lithic or paralithic contact, a petrocalcic horizon, or a duripan if the depth to any of these is <1 m;
         (c) 90 cm if the weighted average particle-size class is loamy between a depth of 25 cm and 1 m or between a depth of 25 cm and a lithic or paralithic contact or a duripan if the depth to any of these is <1 m; or
         (d) 70 cm if the weighted average particle-size class is clayey between a depth of 25 cm and 1 m or between a depth of 25 cm and lithic or paralithic contact, a petrocalcic horizon, or a duripan if the depth to any of these is <1 m; or
2. Have an argillic or a natric horizon and have
   a. An aridic moisture regime; and
   b. An epipedon that is not both massive and hard or very hard when dry.

Aridisols, p. 155 *66*

F. Other soils that have a mesic, isomesic, or warmer temperature regime, do not have tongues of albic materials in the argillic horizon that have vertical dimensions of as much as 50 cm if there is >10 percent weatherable minerals in the 20- to 200-micron fraction, but have one of the following combinations of characteristics:
1. Have an argillic horizon but not a fragipan and have base saturation (by sum or cations) of <35 percent within the following depths:
   a. If the argillic horizon has in some part a hue of 5YR or yellower, or a color value, moist, of 4 or more, or a color value, dry, that is more than 1 unit higher than the value, moist, the shallowest of the following:
      (1) 1.25 m below the upper boundary of the argillic horizon;
      (2) 1.8 m below the surface of the soil; or

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[2] An open crack is interpreted to be a separation between gross polyhedrons. If the surface horizons are strongly self-mulching, that is, if the soil is a mass of loose granules, or if the soil is cultivated while the cracks are open, the cracks may be largely filled with granular materials from the surface. But they are considered to be open in the sense that the polyhedrons are separated.

(3) Immediately above a lithic or paralithic contact;
b. If the argillic horizon has some other color or if the epipedon has a sandy or sandy-skeletal particle-size class throughout, the deeper of 1.25 m below the upper boundary of the argillic horizon, 1.8 m below the surface of the soil, or immediately above a lithic or a paralithic contact if it is shallower;

2. Have a fragipan that
a. Meets all the requirements of an argillic horizon or has clay skins >1 mm thick in some part, or underlies an argillic horizon; and
b. Has base saturation (by sum of cations) of <35 percent at a depth of 75 cm below the upper boundary of the fragipan or immediately above a lithic or paralithic contact, whichever is shallower.

Ultisols, p. 349 84

G. Other soils that
1. Have either of the following:
a. A mollic epipedon; or
b. A surface horizon that, after the soil to a depth of 18 cm is mixed, meets all requirements of a mollic epipedon except thickness, and, in addition, have an upper subhorizon >7.5 cm thick that is in an argillic or a natric horizon, that meets the requirements of a mollic epipedon with respect to color, content of organic carbon, base saturation, and structure but is separated from the surface horizon by an albic horizon; and, in addition,

2. Have base saturation of 50 percent or more (by NH_4OAc) as follows:
a. If there is an argillic or a natric horizon, from its upper boundary to a depth of 1.25 m below that boundary, or to a depth 1.8 m below the soil surface or to a lithic or paralithic contact, whichever is least; or
b. If there is a cambic horizon, in all subhorizons to a depth 1.8 m below the soil surface or to a lithic or paralithic contact, whichever is least; and

3. If the exchange complex is dominated by amorphous materials, have, in some subhorizon within a depth of 35 cm or to a lithic or paralithic contact shallower than 35 cm, a bulk density (at ⅓-bar water tension) of the fine-earth fraction of 0.85 or more and have <60 percent vitric volcanic ash,[3] cinders, or other pyroclastic material in the silt, sand, and gravel fractions within this depth, and

4. If the soil temperature regime is isomesic or a warmer iso temperature regime, the soil has one or more of the following:
a. A horizon that has ≥40 percent $CaCO_3$ equivalent in some subhorizon within 1 m of the surface or above a lithic or paralithic contact, whichever is shallower;
b. A lithic or paralithic contact within 50 cm of the surface and <35 percent clay that has montmorillonitic mineralogy in subhorizons that have a total thickness of ≥25 cm or a COLE of ≥0.09 if the moisture regime is udic or ≥0.07 if the moisture regime is ustic;
c. No cracks at some period in most years that are 1 cm or more wide at a depth of 50 cm, that are at least 30 cm long in some part, and that extend upward to the soil surface or to the base of an Ap horizon if accompanied by all the following characteristics:
(1) COLE of ≥0.09 if the moisture regime is udic or of ≥0.07 if the moisture regime is ustic in a horizon or horizons at least 50 cm thick;
(2) A potential linear extensibility of 6 cm or more in the upper 1 m of the soil if the moisture regime is udic, in the upper 1.25 m of the soil if the moisture regime is ustic, or in the whole soil if there is a lithic or paralithic contact between a depth of 50 cm and 1 m (udic) or 1.25 m (ustic); and
(3) More than 35 percent clay in horizons that total 50 cm or more in thickness;

Mollisols, p. 271 75

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[3] Vitric material, as used here, includes glass and also crystalline particles that are coated with glass or with partly devitrified glass.

H. Other soils that

1. Have a argillic or natric horizon but no fragipan; or
2. Have a fragipan that
   a. Is in or underlies an argillic horizon; or
   b. Meets all requirements of an argillic horizon; or
   c. Has clay skins >1 mm thick in some part.

Alfisols, p. 95 62

I. Other soils that have

1. One or more of the following:
   a. An umbric, mollic, or plaggen epipedon;
   b. A histic epipedon composed of mineral soil materials and, to a depth of 35 cm or more or to a lithic or paralithic contact if one is shallower than 35 cm, either the soil has a bulk density (at 1/3-bar water retention) in the fine-earth fraction that is <0.85 g per cubic centimeter and the exchange complex is dominated by amorphous materials, or the soil is 60 percent or more (by weight) vitric[3] volcanic ash, cinders, or other vitric pyroclastic material;
   c. A cambic horizon or both an aquic moisture regime and permafrost;
   d. Within 1 m of the surface, a calcic, petrocalcic or placic horizon or a duripan; or
   e. A fragipan;
2. Or one of the following:
   a. A sulfuric horizon whose upper boundary is within 50 cm of the soil surface;
   b. In half or more of the upper 50 cm, an SAR of ≥ 13[4] (or sodium saturation that is ≥ 15 percent) that decreases with depth below 50 cm and, within a depth of 1 m, have ground water at some period during the year when the soil is not frozen in any part; or
   c. An n value of ≤ 0.7 or <8 percent clay in all subhorizons between 20 and 50 cm below the mineral surface;
3. No sulfidic material within 50 cm of the soil surface.

Inceptisols, p. 227 72

J. Other soils.

Entisols, p. 179 67

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[4] The percentage of exchangeable sodium (ESP) is used in the definition of the natric horizon and in a number of the taxa. Since this text was written, the U.S. Salinity Laboratory (personal communication from C. A. Bower) has revised its definition of sodic (alkali) soils and the method for measuring the sodium adsorption ratio (SAR) as follows: SAR is measured by the normal method if the conductivity (EC) of the saturation extract is <20 mmhos per cm at 25° C. If the conductivity is ≥ 20 mmhos and SAR is >10, SAR is determined on a sample that has been leached with distilled water until EC of the leachate decreases to about 4 mmhos per centimeter but not to <4. ESP of ≥ 15 is replaced by SAR of ≥ 13 if EC is large enough to require a correction for soluble salts in calculating ESP. If EC is low enough (≤ 4) that no correction is needed for soluble salts, ESP is determined directly from the replaced cations.

Alfisols

Key to suborders

HA. Alfisols that have an aquic moisture regime or are artificially drained and that have characteristics associated with wetness, namely, mottles, or iron-manganese concentrions >2 mm in diameter, or chroma of 2 or less immediately below any Ap horizon or below any dark A1 horizon in which the moist color value is less than 3.5 after the material is rubbed, and one of the following:

1. Dominant chroma of 2 or less[1] in coatings on the surface of peds and mottles within peds of the argillic horizon, or a dominant chroma of 2 or less in the matrix of the argillic horizon and mottles of higher chroma;
2. If there are no mottles in the argillic horizon, a dominant chroma of 1 or less.

Aqualfs, p. 109 *62*

HB. Other Alfisols that have

1. A frigid temperature regime but do not have a xeric moisture regime; or
2. A cryic temperature regime.

Boralfs, p. 119 *63*

HC. Other Alfisols that have one of the following:

1. An ustic moisture regime;
2. An epipedon that is both massive and hard or very hard when dry and a moisture regime that is aridic but marginal to ustic;
3. Within a depth of 1.5 m of the surface or within a depth of 50 cm below the base of the argillic horizon, a calcic horizon or soft powdery lime in spheroidal forms or as coatings on peds or disseminated in particles of clay size[2] and a moisture regime that is udic but marginal to ustic.

Ustalfs, p. 137 *64*

HD. Other Alfisols that have one of the following:

1. A xeric moisture regime; or
2. An epipedon that is both massive and hard or very hard when dry and a moisture regime that is aridic but marginal to xeric.

Xeralfs, p. 146 *65*

HE. Other Alfisols that have a udic moisture regime.

Udalfs, p. 125 *63*

Aqualfs

Key to great groups

HAA. Aqualfs that have plinthite that forms a continuous phase or constitutes half or more of the matrix within some subhorizon between 30 cm and 1.25 m below the surface of the soil.

Plinthaqualfs, p. 117

HAB. Other Aqualfs that have a natric horizon and do not have a duripan.

Natraqualfs, p. 114

HAC. Other Aqualfs that have a duripan.

Duraqualfs, p. 111

HAD. Other Aqualfs that have an isomesic or a warmer iso temperature regime.

Tropaqualfs, p. 117

HAE. Other Aqualfs that have a fragipan.

Fragiaqualfs, p. 111

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[1] If the hue is redder than 10YR because of red parent materials that remain red after citrate-dithionite extraction, the requirement for low chroma is waived. Where the soil temperature regime is hyperthermic, isothermic, or isohyperthermic, chroma up to 4 is tentatively permitted if the hue is 2.5Y or 5Y and if mottles are distinct or prominent. Such soils are too few in the United States to permit testing these limits.

[2] If the lime is disseminated, the horizon(s) in which lime is concentrated should have more lime than the underlying horizon and should have the maximum percentage of clay-size lime.

HAF. Other Aqualfs that have an albic horizon tonguing into an argillic horizon.

Glossaqualfs, p. 112

HAG. Other Aqualfs that have an abrupt textural change between an ochric epipedon or an albic horizon and an argillic horizon and have slow or very slow hydraulic conductivity in the argillic horizon.

Albaqualfs, p. 109

HAH. Other Aqualfs that have an umbric epipedon.

Umbraqualfs, p. 118

HAI. Other Aqualfs.

Ochraqualfs, p. 115

Boralfs

Key to great groups

HBA. Boralfs that have an argillic horizon with its upper boundary deeper than 60 cm below the mineral surface,[7] that have texture finer than loamy fine sand in some subhorizon above the argillic horizon, and that have albic materials tonguing or interfingering in the argillic horizon.

Paleboralfs, p. 124

HBB. Other Boralfs that have a fragipan.

Fragiboralfs, p. 122

HBC. Other Boralfs that have a natric horizon.

Natriboralfs, p. 124

HBD. Other Boralfs that have a cryic temperature regime.

Cryoboralfs, p. 119

HBE. Other Boralfs that have base saturation (by sum of cations) of 60 percent or more in all subhorizons of the argillic horizon and are dry in some horizon at some time in most years.

Eutroboralfs, p. 121

HBF. Other Boralfs that either are never dry in any horizon in most years or have base saturation (by sum of cations) of <60 percent in some subhorizon of the argillic horizon.

Glossoboralfs, p. 122

Udalfs

Key to great groups

HEA. Udalfs that have an agric horizon.

Agrudalfs, p. 125

HEB. Other Udalfs that have a natric horizon.

Natrudalfs, p. 133

HEC. Other Udalfs that

1. Do not have a continuous albic horizon above the argillic horizon;
2. Have a broken upper boundary of the argillic horizon; and
3. Have discrete nodules in the argillic horizon that range from 2.5 to 5 cm to about 30 cm in diameter; exteriors of nodules are enriched and weakly cemented or indurated with iron and have redder hue or stronger chroma than interiors of nodules.

Ferrudalfs, p. 126

HED. Other Udalfs that have tongues of albic materials in the argillic horizon and do not have a fragipan.

Glossudalfs, p. 128

HEE. Other Udalfs that have tongues of albic materials in the argillic horizon and have a fragipan.

Fraglossudalfs, p. 128

HEF. Other Udalfs that have a fragipan.

Fragiudalfs, p. 126

HEG. Other Udalfs that

1. Have mean summer and mean winter soil temperatures at a depth of 50 cm that differ by 5° C or more;

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[7] If there is a surface mantle that has >60 percent vitric volcanic ash, cinders, or other vitric pyroclastic materials, the depth to the argillic horizon is measured from the base of this mantle rather than from the surface of the mineral soil.

2. Do not have a lithic or paralithic contact within 1.5 m of the soil surface;
3. Have clay distribution such that the percentage of clay does not decrease by as much as 20 percent of the maximum within a depth of 1.5 m from the soil surface or the horizon in which the clay decreases either has >5 percent plinthite by volume or has skeletans or other evidence of clay eluviation; and
4. Have one or more of the following:
   a. Hue redder than 10YR and chroma more than 4 dominant in the matrix in at least the lower part of the argillic horizon;
   b. Hue of 2.5YR or redder and value, moist, of less than 4 and value, dry, of less than 5 throughout the major part of the argillic horizon;
   c. Many coarse mottles that have hue redder than 7.5YR or chroma more than 5. or both.

Paleudalfs, p. 133

HEH. Other Udalfs that have an argillic horizon that has throughout its thickness a hue redder than 5YR, a color value, moist of less than 4, and a color value, dry, no more than 1 unit higher than the value, moist.

Rhodudalfs, p. 136

HEI. Other Udalfs that have mean summer and mean winter soil temperatures that differ by <5° C at a depth of 50 cm or at a lithic or a paralithic contact, whichever is shallower.

Tropudalfs, p. 136

HEJ. Other Udalfs.

Hapludalfs, p. 129

Ustalfs

Key to great groups

HCA. Ustalfs that have a duripan that has its upper boundary within 1 m of the surface.

Durustalfs, p. 138

HCB. Other Ustalfs that have plinthite that forms a continuous phase or constitutes more than half the matrix within some subhorizon of the argillic horizon within 1.25 m of the surface.

Plinthustalfs, p. 145

HCC. Other Ustalfs that have a natric horizon.

Natrustalfs, p. 141

HCD. Other Ustalfs that either have a petrocalcic horizon that has its upper boundary within 1.5 m of the surface or have an argillic horizon that meets one or both of the following requirements:

1. Does not have a lithic or paralithic contact within 1.5 m of the surface; and
   a. Has a clay distribution such that the percentage of clay does not decrease by as much as 20 percent of the maximum within a depth of 1.5 m from the soil surface, or the horizon in which the clay decreases either has >5 percent plinthite by volume or has skeletans or evidences of clay eluviation; and
   b. Has one or more of the following:
      (1) Hues redder than 10YR and chroma of more than 4 in the matrix of at least the lower part of the horizon;
      (2) Hues of 7.5YR or redder and value, moist, that is less than 4 and value, dry, that is less than 5 throughout the major part of the horizon; or
      (3) Common coarse mottles that have hue of 7.5YR or redder or chroma of more than 5; or
2. Does not have a lithic or paralithic contact within 50 cm of the surface and has an argillic horizon in which the upper part has a clayey particle-size class and there is an increase of at least 20 percent clay (absolute) within a vertical distance of 7.5 cm, or of at least 15 percent clay (absolute) within a vertical distance of 2.5 cm at the upper boundary.

Paleustalfs, p. 142

HCE. Other Ustalfs that have an argillic horizon that has throughout its thickness a hue redder than 5YR, a color value, moist, less than 4, and a color value, dry, no more than one unit higher than the value moist.

Rhodustalfs, p. 145

HCF. Other Ustalfs

Haplustalfs, p. 138

Xeralfs

Key to great groups

HDA. Xeralfs that have a duripan whose upper boundary is within 1 m of the soil surface but below an argillic or a natric horizon.

Durixeralfs, p. 147

HDB. Other Xeralfs that have plinthite that forms a continuous phase in or constitutes more than half the matrix of some subhorizon of the argillic horizon within 1.25 m of the soil surface.

Plinthoxeralfs, p. 153

HDC. Other Xeralfs that have a natric horizon.

Natrixeralfs, p. 150

HDD. Other Xeralfs that have an argillic horizon that, in all parts, has a color hue redder than 5YR and a value, moist, less than 4 and a value, dry, no more than one unit higher than the value, moist.

Rhodoxeralfs, p. 153

HDE. Other Xeralfs that have either a petrocalcic horizon whose upper boundary is within 1.5 m of the soil surface or have one or both of

1. A vertical clay distribution such that the percentage of clay does not decrease from the maximum by as much as 20 percent of that maximum throughout a depth of 1.5 m from the soil surface, or the horizon in which the clay decreases has either
   a. More than 5 percent by volume of plinthite; or
   b. Skeletans or other evidences of clay eluviation, and there is no lithic or paralithic contact within 1.5 m of the soil surface, and either
      (1) A hue redder than 10YR and chroma more than 4 in the matrix of at least the lower part of the argillic horizon; or
      (2) Common coarse mottles that have a hue of 7.5YR or redder or chroma greater than 5 or both;
2. An argillic horizon that has a clayey particle-size class in the upper part and an increase of at least 20 percent clay (absolute) within a vertical distance of 7.5 cm or at least 15 percent clay (absolute) within a vertical distance of 2.5 cm at the upper boundary; and there is no lithic or paralithic contact within 50 cm of the surface of the soil.

Palexeralfs, p. 151

HDF. Other Xeralfs.

Haploxeralfs, p. 148

Aridisols

Key to suborders

EA. Aridisols that have an argillic or a natric horizon.
Argids, p. 157

EB. Other Aridisols.
Orthids, p. 167

Argids

Key to great groups

EAA. Argids that have a duripan[1] below an argillic horizon and do not have a natric horizon.
Durargids, p. 157

EAB. Other Argids that have a duripan below a natric horizon.
Nadurargids, p, 162

EAC. Other Argids that have a natric horizon and do not have a petrocalcic horizon.
Natrargids, p. 163

EAD. Other Argids that do not have a lithic or paralithic contact within 50 cm of the soil surface, that have a petrocalcic horizon or that have an argillic horizon that has 35 percent or more clay in some part, and that have either:

1. An increase of 15 percent or more clay (absolute) within a vertical distance of 2.5 cm at the upper boundary of the argillic horizon; or
2. An increase of 10 percent or more clay (absolute) if cultivated and the lower boundary of the Ap horizon is the upper boundary of the argillic horizon.

Paleargids, p. 165

EAE. Other Argids.
Haplargids, p. 159

Orthids

Key to great groups

EBA. Orthids that have a salic horizon whose upper boundary is within 75 cm of the soil surface and are saturated with water within a depth of 1 m for 1 month or more in most years or have artificial drainage and lack a duripan that has an upper boundary within 1 m of the soil surface.
Salorthids, p. 177

EBB. Other Orthids that have a petrocalcic horizon whose upper boundary is within 1 m of the soil surface and is not overlain by a duripan.
Paleorthids, p. 176

EBC. Other Orthids that have a duripan whose upper boundary is within 1 m of the soil surface.
Durorthids, p. 174

EBD. Other Orthids that have a gypsic or petrogypsic horizon whose upper boundary is within 1 m of the soil surface.
Gypsiorthids, p. 175

EBE. Other Orthids that have a calcic horizon whose upper boundary is within 1 m of the surface and that are calcareous in all parts above the calcic horizon after the upper soil, to a depth of 18 cm, is mixed unless the texture is as coarse or coarser than loamy fine sand.
Calciorthids, p. 168

EBF. Other Orthids (that have a cambic horizon).
Camborthids, p. 170

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[1] A duripan or a petrocalcic horizon must have its upper boundary within 1 m of the surface to be diagnostic in Aridisols.

Entisols

Key to suborders

JA. Entisols that

1. Have sulfidic materials within 50 cm of the mineral soil surface; or
2. Are permanently saturated with water and have in all horizons below 25 cm
   a. Dominant hue that is neutral or bluer than 10Y and
   b. Colors that change on exposure to the air; or
3. Are saturated with water at some time of year or are artificially drained and have, within 50 cm of the surface, dominant color (moist) in the matrix as follows:
   a. In horizons that have texture finer than loamy fine sand in some or all subhorizons, or that have >35 percent (by volume) of rock fragments in some subhorizon
      (1) If there is mottling, chroma is 2 or less;
      (2) If there is no mottling and the value is less than 4, chroma is less than 1; if the value is 4 or more, chroma is 1 or less;
   b. In horizons that have texture of loamy fine sand or coarser in all subhorizons
      (1) If the hue is as red or redder than 10YR and there is mottling, chroma is 2 or less; if there is no mottling and the value is less than 4, chroma is less than 1; or if the value is 4 or more, chroma is 1 or less;
      (2) If the hue is between 10YR and 10Y and there is distinct or prominent mottling, chroma is 3 or less; if there is no mottling, chroma is 1 or less;
      (3) Hue is bluer than 10Y; or
      (4) Any color if the color is due to uncoated grains of sand.

Aquents, p. 181 68

JB. Other Entisols that have fragments of diagnostic horizons between 25 cm and 1 m below the surface, but the fragments are not arranged in discernible order.

Arents, p. 187 68

JC. Other Entisols that have below the Ap horizon or below a depth of 25 cm, whichever is deeper, <35 percent (by volume) of rock fragments and that have texture of loamy fine sand or coarser in all subhorizons [1] either to a depth of 1 m or to a lithic, paralithic, or petroferric contact, whichever is shallower.

Psamments, p. 202 69

JD. Other Entisols that do not have a lithic or paralithic contact within 25 cm of the soil surface and that have slopes of <25 percent and organic-carbon content that decreases irregularly with depth or remains above a level of 0.2 percent to a depth of 1.25 m, and the mean annual soil temperature is higher than 0° C. (Strata of sand or loamy sand may have less organic carbon if finer sediments at a depth of 1.25 m or below have 0.2 percent organic carbon or more.)

Fluvents, p. 187 68

JE. Other Entisols.

Orthents, p. 194 69

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[1] Lamellae that are <1 cm thick or that are too few to meet the requirements for an argillic horizon are permitted to have texture of sandy loam. See the definition of an argillic horizon

Aquents

Key to great groups

JAA. Aquents that have sulfidic materials within 50 cm of the mineral soil surface.

Sulfaquents, p. 186

JAB. Other Aquents that have an *n* value of >0.7 and that have at least 8 percent clay in all subhorizons between a depth of 20 and 50 cm and that have a mean annual soil temperature higher than 0° C.

Hydraquents, p. 185

JAC. Other Aquents that have a cryic but not a pergelic [2] soil temperature regime.

Cryaquents, p. 181

JAD. Other Aquents that have an organic-carbon content [3] that decreases irregularly with depth or that remains above 0.2 percent to a depth of 1.25 m; and that have texture finer than loamy fine sand in some or all subhorizons between the Ap horizon or a depth of 25 cm, whichever is deeper, and 1 m or a lithic or paralithic contact, whichever is shallower. Thin strata of sand may have less organic carbon if the finer sediments at a depth of 1.25 m or below have 0.2 percent organic carbon or more.

Fluvaquents, p. 182

JAE. Other Aquents that have a difference of <5° C between the mean summer and mean winter soil temperatures at a depth of 50 cm.

Tropaquents, p. 187

JAF. Other Aquents that have a sandy particle-size class in all subhorizons between the Ap horizon or a depth of 25 cm, whichever is deeper, and 1 m or a lithic or paralithic contact, whichever is shallower, and that have mean summer and mean winter soil temperatures at a depth of 50 cm that differ by 5° C or more.

Psammaquents, p. 185

JAG. Other Aquents.

Haplaquents, p. 184

Arents

The Arents form a unique suborder in that not only are no great groups recognized, but also there is no typic subgroup. Subgroups of Arents are intergrades to suborders or great groups of Spodosols, Alfisols, or other orders, according to the nature of the fragments that can be identified and according to the soil moisture and soil temperature regimes of the suborders.

Fluvents

Key to great groups

JDA. Fluvents that have a cryic soil temperature regime.

Cryofluvents, p. 188

JDB. Other Fluvents that have a xeric moisture regime.

Xerofluvents, p. 193

JDC. Other Fluvents that have an ustic moisture regime.

Ustifluvents, p. 191

JDD. Other Fluvents that have a torric moisture regime.

Torrifluvents, p. 189

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[2] Soils that otherwise could be Aquents are grouped with Aquepts if there is permafrost.

[3] The carbon should be of Holocene age. It is not the intent to include fossil carbon from transported fragments of bedrock or from buried Pleistocene deposits. The mean residence time of the carbon should be <11,000 years B.P.

JDE. Other Fluvents that have an isomesic, isothermic, or isohyperthermic temperature regime.

Tropofluvents, p. 190

JDF. Other Fluvents.

Udifluvents, p. 190

Orthents

Key to great groups

JEA. Orthents that have a cryic or pergelic temperature regime.

Cryorthents, p. 195

JEB. Other Orthents that have a torric moisture regime or that have a conductivity of the saturation extract that is 2 mmho per centimeter or greater at 25° C in some part above whichever of the following depths is the least: a lithic or paralithic contact or 1.25 m if particle-size class [11] is sandy, 90 cm if loamy, and 75 cm if clayey.

Torriorthents, p. 196

JEC. Other Orthents that have a xeric moisture regime.

Xerorthents, p. 201

JED. Other Orthents that have a udic moisture regime and mean summer and mean winter soil temperatures at a depth of 50 cm that differ by $<5°$ C.

Troporthents, p. 198

JEE. Other Orthents that have a udic moisture regime.

Udorthents, p. 199

JEF. Other Orthents.

Ustorthents, p. 200

Psamments

Key to great groups

JCA. Psamments that have a cryic or pergelic soil temperature regime.

Cryopsamments, p. 202

JCB. Other Psamments that have a torric moisture regime.

Torripsamments, p. 204

JCC. Other Psamments that have a sand fraction that is 95 percent or more quartz, zircon, tourmaline, rutile, and other normally insoluble crystalline minerals that do not weather to liberate iron or aluminum.

Quartzipsamments, p. 203

JCD. Other Psamments that have a udic moisture regime and mean summer and mean winter soil temperatures at a depth of 50 cm that differ by 5° C or more.

Udipsamments, p. 205

JCE. Other Psamments that have a udic moisture regime.

Tropopsamments, p. 205

JCF. Other Psamments that have a xeric moisture regime.

Xeropsamments, p. 207

JCG. Other Psamments.

Ustipsamments, p. 207

[11] The weighted average particle-size class between a depth of 25 cm and either a depth of 1 m or a lithic or paralithic contact, whichever is shallower.

Histosols

Key to suborders

AA. Histosols that
1. Are never saturated with water for more than a few days following heavy rains and
   a. Have a lithic or paralithic contact <1 m from the surface or have fragmental materials in which the interstices are filled or partly filled with organic materials in half or more of each pedon, or both; and
   b. Less than three-fourths of the thickness of organic materials consists of *Sphagnum* fibers.

Folists, p. 217 71

AB. Other Histosols that
1. Are dominantly[1] fibric in the subsurface tier if that tier is wholly organic except for a thin mineral layer or layers, or the organic parts of the surface and subsurface tiers are dominantly fibric if a continuous mineral layer 40 cm or more thick begins within the depth limit of the subsurface tier; or
2. Have a surface mantle that has three-fourths or more of its volume consisting of fibers derived from *Sphagnum* and that rests on a lithic or paralithic contact, fragmental materials, or mineral soil, or on frozen[2] materials within the limits in depth of the surface or subsurface tier; and
3. Do not have a sulfuric horizon whose upper boundary is within 50 cm of the surface and do not have sulfidic materials within 1 m of the surface.

Fibrists, p. 212 70

AC. Other Histosols that
1. Are dominantly hemic in the subsurface tier if that tier is wholly organic except for a thin mineral layer or layers; or are dominantly hemic in the organic part of the surface and subsurface tiers if a continuous mineral layer 40 cm or more thick begins within the depth limits of the subsurface tier; or
2. Have a sulfuric horizon whose upper boundary is within 50 cm of the surface or have sulfidic materials within 1 m of the surface.

Hemists, p. 219 71

AD. Other Histosols.

Saprists, p. 223 71

Fibrists

Key to great groups

ABA. Fibrists that have a surface mantle that is three-fourths or more fibric *Sphagnum* spp. and that either is 90 cm or more thick, or extends 10 cm or more below permafrost, or rests on a lithic or paralithic contact, fragmental materials, or mineral soil materials.

Sphagnofibrists, p. 215

ABB. Other Fibrists that are frozen in most years in some layer within the control section about 2 months after the summer solstice or that are never frozen in most years below a depth of 5 cm but have a mean annual soil temperature that is lower than 8° C.

Cryofibrists, p. 214

ABC. Other Fibrists that have a mean annual soil temperature lower than 8° C.

Borofibrists, p. 213

[1] Dominant, in this context, means the most abundant. If only two kinds of organic materials are present, the fibric materials occupy half or more of the volume. If there are both hemic and sapric materials as well as fibric, the fibric materials may occupy less than half of the volume but have more volume than either the hemic or sapric materials.

[2] Frozen 2 months after the summer solstice.

ABD. Other Fibrists that have a difference of <5° C between mean summer and mean winter soil temperatures at a depth of 30 cm.

Tropofibrists, p. 217

ABE. Other Fibrists that do not have a horizon 2 cm or more thick that is half or more humilluvic materials.

Medifibrists, p. 214

ABF. Other Fibrists.

Luvifibrists, p. 214

Folists

Key to great groups

AAA. Folists that have a cryic or colder temperature regime.

Cryofolists, p. 219

AAB. Other Folists that have an isomesic or warmer temperature regime.

Tropofolists, p. 219

AAC. Other Folists that have a frigid temperature regime.

Borofolists, p. 218

Hemists

Key to great groups

ACA. Hemists that have a sulfuric horizon that has its upper boundary within 50 cm of the surface.

Sulfohemists, p. 222

ACB. Other Hemists that have sulfidic materials within 1 m of the surface.

Sulfihemists, p. 222

ACC. Other Hemists that have a horizon 2 cm or more thick in which half or more of the volume is humilluvic materials.

Luvihemists, p. 221

ACD. Hemists that are frozen in some layers within the control section about 2 months after the summer solstice in most years or that are never frozen below a depth of 5 cm in most years but have a mean annual soil temperature lower than 8° C.

Cryohemists, p. 221

ACE. Other Hemists that have a mean annual soil temperature lower than 8° C.

Borohemists, p. 220

ACF. Other Hemists that have a difference of <5° C between mean summer and mean winter soil temperatures at a depth of 30 cm.

Tropohemists, p. 223

ACG. Other Hemists.

Medihemists, p. 221

Saprists

Key to great groups

ADA. Saprists that are frozen in some layer within the control section about 2 months after the summer solstice or that are never frozen below a depth of 5 cm but have a mean annual soil temperature lower than 8° C.

Cryosaprists, p. 224

ADB. Other Saprists that have a mean annual soil temperature lower than 8° C.

Borosaprists, p. 224

ADC. Other Saprists that have <5° C difference between summer and mean winter soil temperatures at a depth of 30 cm.

Troposaprists, p. 226

ADD. Other Saprists that do not have a horizon of humilluvic materials 2 cm or more thick.

Medisaprists, p. 225

In addition to the great groups listed in the key, a great group of Vermisaprists may be needed, particularly for soils that have been drained for a long time, but a definition cannot be suggested at present.

Inceptisols

Key to suborders

IA. Inceptisols that

1. Have an aquic moisture regime or are artificially drained and have one or more of the following:
   a. A histic epipedon;
   b. A sulfuric horizon that has its upper boundary within 50 cm of the mineral soil surface;
   c. An umbric or mollic epipedon that is underlain immediately or at a depth <50 cm below the soil surface by a horizon that has dominant colors, moist, on ped faces, or in the matrix if peds are absent, as follows:
      (1) If there is mottling, chroma is 2 or less;[3]
      (2) If there is no mottling, chroma is 1 or less;
   d. An ochric epipedon that is underlain at a depth <50 cm below the soil surface by a layer that has dominant color, moist, on ped faces, or in the matrix if peds are absent, as follows:
      (1) If there is mottling, chroma is 2 or less;[3]
      (2) If there is no mottling, chroma is 1 or less;
2. Or have on SAR ≥ 13 (or sodium saturation that is 15 percent or more) in half or more of the soil to a depth of 50 cm that decreases with depth below 50 cm and ground water within 1 m of the surface at some time of year.

Aquepts, p. 236 73

IB. Other Inceptisols that have to a depth of 35 cm or more, or to a lithic or paralithic contact if one is shallower than 35 cm, one or both of the following:

1. Bulk density (at 1/3-bar water retention) of the fine-earth fraction that is <0.85 g per cubic centimeter and an exchange complex that is dominated by amorphous materials; or
2. Sixty percent or more of the soil (by weight) is vitric[4] volcanic ash, cinders or other pyroclastic materials.

Andepts, p. 230 72

IC. Other Inceptisols that have a plaggen epipedon.

Plaggepts, p. 257 74

ID. Other Inceptisols that have an isomesic or warmer iso temperature regime.

Tropepts, p. 257 74

IE. Other Inceptisols that have an ochric epipedon; or that have an umbric or mollic epipedon that is <25 cm thick and have also a mesic or warmer soil temperature regime.

Ochrepts, p. 246 74

IF. Other Inceptisols.

Umbrepts, p. 264 74

Andepts

Key to great groups

IBA. Andepts that have a cryic or pergelic temperature regime.

Cryandepts, p. 231

IBB. Other Andepts that have a duripan that has its upper boundary within 1 m of the soil surface.

Durandepts, p. 232

IBC. Other Andepts that have clays that dehydrate irreversibly into aggregates of sand and gravel size.

Hydrandepts, p. 234

IBD. Other Andepts that have a placic horizon within 1 m of the soil surface in half or more of each pedon.

Placandepts, p. 235

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[3] If the hue is redder than 10YR because of red parent materials that remain red after citrate-dithionite extraction, the requirement for low chroma is waived.

IBE. Other Andepts that are not thixotropic and in which the weighted average 15-bar water retention[5] of the fine-earth fraction is <20 percent for all horizons between a depth of 25 cm and 1 m or between 25 cm and a lithic or paralithic contact if one is shallower than 1 m.

Vitrandepts, p. 235

IBF. Other Andepts that have a base saturation (by NH_4OAc) of 50 percent or more in some subhorizon between a depth of 25 and 75 cm.

Eutrandepts, p. 233

IBG. Other Andepts.

Dystrandepts, p. 232

Aquepts

Key to great groups

IAA. Aquepts that have a sulfuric horizon whose upper boundary is within 50 cm of the mineral soil surface.

Sulfaquepts, p. 245

IAB. Other Aquepts that have a placic horizon within 1 m of the mineral soil surface in half or more of each pedon.

Placaquepts, p. 244

IAC. Other Aquepts that have an SAR ≥13 (or have sodium saturation that is ≥15 percent) in half or more of the upper 50 cm of soil that decreases with depth below 50 cm.

Halaquepts, p. 240

IAD. Other Aquepts that have a fragipan.

Fragiaquepts, p. 239

IAE. Other Aquepts that have a cryic or pergelic soil temperature regime.

Cryaquepts, p. 238

IAF. Other Aquepts that have plinthite that forms a continuous phase or constitutes more than half the matrix within some subhorizon in the upper 1.25 m of the soil.

Plinthaquepts, p. 245

IAG. Other Aquepts that have, to a depth of 35 cm or more or to a lithic or paralithic contact if one is shallower than 35 cm, one or both of the following:

1. Bulk density (at 1/3-bar water retention) of the fine-earth fraction that is <0.85 g per cubic centimeter and an exchange complex that is dominated by amorphous materials; or
2. Sixty percent or more of the soil (by weight) is vitric[1] volcanic ash, cinders, or other pyroclastic materials.

Andaquepts, p. 237

IAH. Other Aquepts that have a difference of <5° C between the mean summer and mean winter soil temperatures at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower.

Tropaquepts, p. 245

IAI. Other Aquepts that have an umbric, a mollic, or a histic epipedon.

Humaquepts, p. 243

IAJ. Other Aquepts.

Haplaquepts, p. 241

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[1] Included in the meaning of vitric materials in this definition are crystalline particles that are coated with glass and partially devitrified glass as well as glass.

[5] The amount of water retained at a tension of 15 bars may be reduced by drying these soils. Since 15-bar water retention is used as a measure of effective clay content, it would be unrealistic to use the extremely high value obtained on a field-moist Andept. That value reflects mostly the climatic history rather than a basic soil property. The value for 15-bar water retention that is referred to here, therefore, is that of a sample that has been dried at 40° C.

Ochrepts

Key to great groups

IEA. Ochrepts that have a fragipan.
Fragiochrepts, p. 253

IEB. Other Ochrepts that have a duripan whose upper boundary is within 1 m of the soil surface.
Durochrepts, p. 248

IEC. Other Ochrepts that have a cryic or pergelic temperature regime.
Cryochrepts, p. 247

IED. Other Ochrepts that have an ustic moisture regime.
Ustochrepts, p. 254

IEE. Other Ochrepts that have a xeric moisture regime.
Xerochrepts, p. 255

IEF. Other Ochrepts that have one or both of the following:
1. Carbonates in the cambic horizon or in the C horizon but within the soil; or
2. Base saturation (by NH_4OAc) that is 60 percent or more in some subhorizon between depths of 25 and 75 cm below the soil surface.

Eutrochrepts, p. 251

IEG. Other Ochrepts.
Dystrochrepts, p. 249

Plaggepts

Plaggepts are the soils that have a plaggen epipedon that is composed of crystalline rather than pyroclastic materials. This suborder includes all freely drained soils that have a plaggen epipedon except a few Andepts.

Tropepts

Key to great groups

IDA. Tropepts that have base saturation of <50 percent (by NH_4OAc) in some subhorizon between depths of 25 cm and 1 m and have 12 kg or more organic carbon, exclusive of surface litter, per square meter in the soil to a depth of 1 m, or to a lithic, paralithic, or petroferric contact if one is shallower than 1 m, and do not have a sombric horizon.
Humitropepts, p. 261

IDB. Other Tropepts that have a sombric horizon.
Sombritropepts, p. 262

IDC. Other Tropepts that have an ustic moisture regime or have soft powdery lime within 1.5 m of the soil surface and have base saturation (by NH_4OAc) of 50 percent or more in all subhorizons between depths of 25 cm and 1 m, or between 25 cm and a lithic, paralithic or petroferric contact if one is shallower than 1 m.
Ustropepts, p. 262

IDD. Other Tropepts that have base saturation (by NH_4OAc) of 50 percent or more in all subhorizons between depths of 25 cm and 1 m, or between 25 cm and a lithic or paralithic contact if one is shallower than 1 m.
Eutropepts, p. 260

IDE. Other Tropepts.
Dystropepts, p. 258

Umbrepts

Key to great groups

IFA. Umbrepts that have a fragipan.
Fragiumbrepts, p. 265

IFB. Other Umbrepts that have a cryic or pergelic temperature regime.
Cryumbrepts, p. 264

IFC. Other Umbrepts that have a xeric moisture regime.
Xerumbrepts, p. 268

IFD. Other Umbrepts.
Haplumbrepts, p. 266

Mollisols

Key to suborders

GA. Mollisols that have all the following:

1. An albic horizon that lies immediately under the mollic epipedon or that separates horizons that together meet all the requirements of a mollic epipedon;
2. An argillic or a natric horizon; and
3. Chroma of 2 or less in the albic horizon or characteristics associated with wetness in the albic, argillic, or natric horizon, namely mottles or iron-manganese concretions larger than 2 mm or both.

Albolls, p. 273 76

GB. Other Mollisols that either have an aquic moisture regime or are artificially drained, and that have one or more of the following characteristics associated with wetness:

1. A histic epipedon overlying the mollic epipedon;
2. An SAR ≥ 13 (or sodium saturation of ≥ 15 percent) in the upper part of the mollic epipedon and decreasing SAR (or sodium saturation) with increasing depth below 50 cm;
3. One of the following combinations of colors, moist;
   a. If the lower part of the mollic epipedon [2] has chroma of 1 or less, there are either
      (1) Distinct or prominent mottles in the lower part of the mollic epipedon; or
      (2) A color value, moist, of 4 or more immediately below the mollic epipedon, or within 75 cm of the surface if a calcic horizon intervenes, and one of the following:
         (a) If the hue is 10YR or redder and there are mottles, chroma is less than 1.5 on ped surfaces or in the matrix; if there are no mottles, chroma is less than 1;
         (b) If the hue is nearest 2.5Y and there are distinct or prominent mottles, chroma is 2 or less on ped surfaces or in the matrix; if there are no mottles, chroma is 1 or less;
         (c) If the nearest hue is 5Y or yellower and there are distinct or prominent mottles, chroma is 3 or less on ped surfaces or in the matrix; if there are no mottles, chroma is 1 or less;
         (d) The hue is bluer than 10Y or the color is neutral; or
         (e) The color results from uncoated mineral grains; or
   b. If the lower part of the mollic epipedon has chroma of more than 1 but not more than 2, there are either
      (1) Distinct or prominent mottles in the lower mollic epipedon; or
      (2) Base colors immediately below the mollic epipedon that have one or more of the following properties:
         (a) Value of 4 and chroma of 2 and also some mottles that have value of 4 or more and chroma less than 2;
         (b) Value of 5 or more and chroma of 2 or less and also mottles that have higher chroma; or
         (c) Value of 4 and chroma <2; or
4. A calcic or petrocalcic horizon that has its upper boundary within 40 cm of the surface.

Aquolls, p. 275 76

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[2] If the mollic epipedon extends to a lithic contact within 30 cm of the surface, the requirement for mottles is waived.

[3] If the lime is disseminated, the horizon(s) in which the lime is concentrated should have more lime than the underlying horizon and should have the maximum percentage of clay-size lime

GC. Other Mollisols that have all the following characteristics:
1. Have a mollic epipedon that is not more than 50 cm thick;
2. Do not have an argillic horizon;
3. Do not have a calcic horizon;
4. The soil materials in or immediately below any mollic epipedon, including coarse fragments less than 7.5 cm in diameter, have a $CaCO_3$ equivalent of 40 percent or more; and
5. Have a udic moisture regime or a cryic temperature regime;

Rendolls, p. 293 77

GD. Other Mollisols that have a xeric moisture regime or an aridic moisture regime bordering on xeric but do not have a cryic temperature regime.

Xerolls, p. 310 78

GE. Other Mollisols that have a frigid, cryic, or pergelic temperature regime.

Borolls, p. 281 76

GF. Other Mollisols that have an ustic or an aridic moisture regime that borders on ustic or have, within 1.5 m of the soil surface or within 50 cm below the base of any cambic or argillic horizon, a gypsic horizon, or a calcic horizon, or a ca horizon that has concentrations of soft powdery lime in spheroidal forms or as coatings on peds, or disseminated [3] in clay-size particles.

Ustolls, p. 298 78

GG. Other Mollisols.

Udolls, p. 295 77

Albolls

Key to great groups

GAA. Albolls that have a natric horizon.

Natralbolls, p. 274

GAB. Other Albolls.

Argialbolls, p. 274

Aquolls

Key to great groups

GBA. Aquolls that have a cryic or pergelic temperature regime.

Cryaquolls, p. 277

GBB. Other Aquolls that have a duripan that has its upper boundary within 1 m of the surface.

Duraquolls, p. 278

GBC. Other Aquolls that have a natric horizon.

Natraquolls, p. 280

GBD. Other Aquolls that have a calcic or gypsic horizon that has its upper boundary within 40 cm of the surface and do not have an argillic horizon unless it is a buried horizon.

Calciaquolls, p. 276

GBE. Other Aquolls that have an argillic horizon.

Argiaquolls, p. 276

GBF. Other Aquolls.

Haplaquolls, p. 279

Borolls

Key to great groups

GEA. Borolls that have an argillic horizon that has its upper boundary deeper than 60 cm below the mineral soil surface [5] and that have texture finer than loamy fine sand in all subhorizons above the argillic horizon.

Paleborolls, p. 291

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[5] If there is a surface mantle that has ≥ 60 percent vitric volcanic ash, cinders, or other vitric pyroclastic materials, the depth to the argillic horizon is measured from the base of this mantle rather than from the mineral soil surface.

GEB. Other Borolls that have a cryic or pergelic temperature regime.

Cryoborolls, p. 285

GEC. Other Borolls that have a natric horizon but do not have a cambic horizon that is above the natric horizon and separated from it by an albic horizon.

Natriborolls, p. 291

GED. Other Borolls that have an argillic horizon but do not have a cambic horizon that is above the argillic horizon and separated from it by an albic horizon.

Argiborolls, p. 282

GEE. Other Borolls that have a mollic epipedon that, below any Ap horizon, is 50 percent or more by volume wormholes, wormcasts, or filled animal burrows and that either rests on a lithic contact or has a transition to the underlying horizon in which 25 percent or more of the material is discrete wormholes, wormcasts, or animal burrows filled with material from the mollic epipedon and the underlying horizon.

Vermiborolls, p. 293

GEF. Other Borolls that have a calcic or petrocalcic horizon whose upper boundary is within 1 m of the soil surface and that are calcareous in all parts of all horizons above the calcic or petrocalcic horizon, after the upper soil to a depth of 18 cm has been mixed, unless the texture is coarser than loamy very fine sand.

Calciborolls, p. 284

GEG. Other Borolls.

Haploborolls, p. 288

Rendolls

Rendolls (plate 12A) are the Mollisols of humid regions that were formed mainly under forests from highly calcareous parent materials such as chalk, drift composed mainly of limestone, or shell bars. They have a mollic epipedon that rests on the calcareous parent materials or on a cambic horizon that is rich in carbonates. A few are so rich in finely divided lime, which acts as a white pigment, that the mollic epipedon has a color lighter than normal but is nevertheless rich in dark-colored humus and is within the limits of a mollic epipedon. They have developed at high altitudes and near the equator. They have a udic moisture regime.

Udolls

Key to great groups

GGA. Udolls that have an argillic horizon and a clay distribution such that the clay content does not decrease by 20 percent of the maximum clay content within 1.5 m of the soil surface and there is no lithic or paralithic contact within that depth, and there is one or both of the following features:

1. Hue redder than 10YR and chroma greater than 4 dominant in the matrix in at least the lower part of an argillic horizon; or
2. Many coarse mottles that have hue redder than 7.5 YR or chroma greater than 5.

Paleudolls, p. 297

GGB. Other Udolls that have an argillic horizon.

Argiudolls, p. 295

GGC. Other Udolls that have a mollic epipedon that, below any Ap horizon, is 50 percent or more by volume wormholes, wormcasts, or filled animal burrows and that either rests on a lithic contact or has a transition to an underlying horizon in which 25 percent or more of the material is discrete wormholes, wormcasts, or filled animal burrows that contain material from the mollic epipedon and from the underlying horizon.

Vermudolls, p. 298

GGD. Other Udolls.

Hapludolls, p. 296

Ustolls

Key to great groups

GFA. Ustolls that have a duripan with its upper boundary within 1 m of the soil surface.

Durustolls, p. 303

GFB. Other Ustolls that have a natric horizon.

Natrustolls, p. 306

GFC. Other Ustolls that have a petrocalcic horizon that has its upper boundary within 1.5 m of the soil surface, and that have an argillic horizon or are noncalcareous in some subhorizon above the petrocalcic horizon after the surface soil to a depth of 18 cm has been mixed, or that have an argillic horizon that has one or both of the following:

1. A vertical clay distribution such that the clay content does not decrease by 20 percent of the maximum clay content within 1.5 m of the soil surface and the soil does not have a lithic or paralithic contact within that depth, and the argillic horizon has one or both of these:
   a. A hue redder than 10YR and chroma higher than 4 in the matrix; or
   b. Common coarse mottles that have a hue of 7.5YR or redder or chroma higher than 5; or
2. A particle-size class in the upper part that is clayey and an increase of at least 20 percent clay (absolute) within a vertical distance of 7.5 cm or of 15 percent clay (absolute) within 2.5 cm at the upper boundary, and there is no lithic or paralithic contact within 50 cm of the surface of the soil.

Paleustolls, p. 307

GFD. Other Ustolls that have a calcic horizon that has its upper boundary within 1 m of the soil surface or that have a petrocalcic horizon that has its upper boundary within 1.5 m of the surface, and that are calcareous in all overlying subhorizons after the upper soil to a depth of 18 cm has been mixed, unless the texture is coarser than loamy very fine sand or very fine sand.

Calciustolls, p. 301

GFE. Other Ustolls that have an argillic horizon.

Argiustolls, p. 299

GFF. Other Ustolls that have a mollic epipedon below any Ap horizon that is 50 percent or more by volume wormholes and wormcasts or filled animal burrows, and that either rests on a lithic contact or has a transition to the underlying horizon in which 25 percent or more of the material is discrete wormcasts or animal burrows filled with material from the mollic epipedon and the underlying horizon.

Vermustolls, p. 309

GFG. Other Ustolls.

Haplustolls, p. 303

Xerolls

Key to great groups

GDA. Xerolls that have a duripan within 1 m of the soil surface.

Durixerolls, p. 314

GDB. Other Xerolls that have a natric horizon but do not have a petrocalcic horizon that has its upper boundary within 1.5 m of the soil surface.

Natrixerolls, p. 319

GDC. Other Xerolls that have a petrocalcic horizon that has its upper boundary within 1.5 m of the soil surface or an argillic horizon that has either or both

1. A vertical clay distribution such that the clay content does not decrease by 20 percent of the maximum clay content within 1.5 m of the soil surface, and also one or more of
   a. A hue redder than 10YR and chroma higher than 4 in the matrix; or
   b. Common coarse mottles that have a hue of 7.5YR or redder or chroma higher than 5, or both; or

2. A particle-size class in the upper part that is clayey and an increase in clay content of at least 20 percent clay (absolute) within a vertical distance of 7.5 cm or an increase of 15 percent clay (absolute) within a distance of 2.5 cm at the upper boundary and no lithic or paralithic contact within 50 cm of the soil surface.

Palexerolls, p. 320

GDD. Other Xerolls that have a calcic or gypsic horizon that has its upper boundary within 1.5 m of the soil surface and that are calcareous in all parts of all horizons above the calcic or gypsic horizon after the upper soil to a depth of 18 cm has been mixed unless the texture is coarser than loamy very fine sand or very fine sand.

Calcixerolls, p. 313

GDE. Other Xerolls that have an argillic horizon.

Argixerolls, p. 311

GDF. Other Xerolls.

Haploxerolls, p. 315

Oxisols

Key to suborders

CA. Oxisols that have one or both of the following characteristics:

1. Plinthite that forms a continuous phase within 30 cm of the mineral surface of the soil and the soil is saturated with water within this depth at some time during the year; or
2. Either are saturated with water at some time during the year or are artifically drained, have an oxic horizon, and also have one or both of the following characteristics associated with wetness:
    a. A histic epipedon; or
    b. If free of mottles, immediately below any epipedon that has moist color value of less than 3.5 there is dominant chroma of 2 or less; or if there are distinct or prominent mottles within 50 cm of the soil surface, the dominant chroma is 3 or less.

Aquox, p. 324 80

CB. Other Oxisols that have a torric moisture regime.

Torrox, p. 330 81

CC. Other Oxisols that:

1. Have 16 kg or more organic carbon per square meter to a depth of 1 m, exclusive of organic surface litter;
2. Have a weighted average base saturation in the oxic horizon (by NH_4OAc) of <35 percent; and
3. Have an isothermic, thermic, or cooler temperature regime.

Humox, p. 325 80

CD. Other Oxisols that have an ustic soil moisture regime and an isothermic, thermic, or warmer temperature regime.

Ustox, p. 330 81

CE. Other Oxisols.

Orthox, p. 326 81

Aquox

Key to great groups

CAA. Aquox that either have cemented sheets containing 30 percent or more gibbsite or have 20 percent or more by volume gravel-size aggregates containing 30 percent or more gibbsite within 1 m of the mineral soil surface but that do not have plinthite that forms a continuous phase within 30 cm of the soil surface.

Gibbsiaquox, p. 324

CAB. Other Aquox that have plinthite that forms a continuous phase within 1.25 cm of the soil surface.

Plinthaquox, p. 324

CAC. Other Aquox that have an ochric epipedon.

Ochraquox, p. 324

CAD. Other Aquox.

Umbraquox, p. 325

Humox

Key to great groups

CCA. Humox that have a sombric horizon.

Sombrihumox, p. 326

CCB. Other Humox that have, within 1 m of the soil surface, either cemented sheets that have 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.

Gibbsihumox, p. 326

CCC. Other Humox that have in all subhorizons of the oxic horizon a cation-retention capacity (from NH_4Cl) of >1.5 meq per 100 g clay [2] or that have >1.5 meq of extractable bases plus extractable aluminum per 100 g clay.

Haplohumox, p. 326

CCD. Other Humox.

Acrohumox, p. 325

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[2] See footnote 2 on next page

Orthox

Key to great groups

CEA. Orthox that have a sombric horizon.

Sombriorthox, p. 330

CEB. Other Orthox that have within 1.25 m of the soil surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.

Gibbsiorthox, p. 328

CEC. Other Orthox that
1. Have in some subhorizon of the oxic horizon a cation-retention capacity of 1.5 meq or less (from NH_4Cl) per 100 g clay [2] (or 1.5 meq or less extractable aluminum per 100 g clay); and
2. Do not have discernible structure [5] in the oxic horizon or have only weak blocky or prismatic peds.

Acrorthox, p. 327

CED. Other Orthox that do not have an anthropic epipedon and have base saturation of 35 percent or more (by NH_4OAc) in the epipedon and in all subhorizons of the oxic horizon to a depth of at least 1.25 m.

Eutrorthox, p. 328

CEE. Other Orthox that have either an umbric epipedon or an ochric epipedon that has >1 percent carbon in all subhorizons to a depth of 75 cm or more below the mineral soil surface.

Umbriorthox, p. 330

CEF. Other Orthox.

Haplorthox, p. 329

Torrox

These are the Oxisols of arid climates. They are too dry to be cultivated without at least some irrigation. They are apparently relicts preserved from some former pluvial period or periods. They are dominantly red, have little organic matter, and have relatively high base saturation. If irrigated, they can be highly productive. Their extent in the world is not fully known. They have a torric soil moisture regime and, so far as is known, have an isohyperthermic temperature regime.

Ustox

Key to great groups

CDA. Ustox that have a sombric horizon.

Sombriustox, p. 332

CDB. Other Ustox that have a cation-retention capacity (from NH_4Cl) of 1.5 meq or less per 100 g clay [11] in some subhorizon of the oxic horizon (or have 1.5 meq or less of extractable bases plus extractable aluminum per 100 g clay).

Acrustox, p. 331

CDC. Other Ustox that have base saturation of 50 percent or more (by NH_4OAc) in the major part of the oxic horizon if the particle-size class is clayey or 35 percent or more if the particle-size class is loamy.

Eutrustox, p. 331

CDD. Other Ustox.

Haplustox, p. 332

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[2] Some oxic horizons do not disperse well. The percentage of clay is determined by the higher value of (1) the measured percentage of clay or (2) 2.5 times the percentage of water retained at tension of 15 bars if the ratio of 15-bar water to measured clay is 0.6 or more.

[5] Structure in the macro sense. These soils normally have a strong but extremely fine granular structure that can be seen under a hand lens or in thin sections under a microscope. The individual granules are too fine to be seen with the naked eye.

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Spodosols

Key to suborders

BA. Spodosols that either have an aquic moisture regime[1] or are artificially drained and have characteristics associated with wetness, namely one or more of the following:

1. A histic epipedon;
2. Mottling in an albic horizon or in the upper part of the spodic horizon;
3. A duripan in the albic horizon;
4. If free iron and manganese are absent or if the color value, moist, is less than 4 in the upper part of the spodic horizon, either
   a. Have any color if there are no coatings of iron oxides on the individual grains of silt and sand in or immediately below the spodic horizon wherever the value, moist, is 4 or more; or
   b. Have fine or medium mottles of iron or manganese in the materials immediately below the spodic horizon;
5. A placic horizon that rests on a fragipan or on a spodic horizon or on an albic horizon that is underlain by a spodic horizon but is not in a spodic horizon.

Aquods, p. 334 82

BB. Other Spodosols that have a spodic horizon in which the ratio of free iron (by dithionite-citrate) to carbon (both elemental) is 6 or more in all subhorizons.

Ferrods, p. 340 83

BC. Other Spodosols that have a spodic horizon in which some subhorizon that is present in more than half of each pedon has a ratio of free iron to carbon of <0.2.

Humods, p. 340 83

BD. Other Spodosols.

Orthods, p. 343 83

Aquods

Key to great groups

BAA. Aquods that have a fragipan below the spodic horizon but do not have a placic horizon above the fragipan.

Fragiaquods, p. 335

BAB. Other Aquods that do not have a placic horizon but have a cryic temperature regime.

Cryaquods, p. 334

BAC. Other Aquods that have a strongly cemented or indurated albic horizon that does not slake in water when a dry fragment is immersed.

Duraquods, p. 335

BAD. Other Aquods that have a placic horizon that rests on a spodic horizon or on a fragipan or on an albic horizon that rests on a spodic horizon.

Placaquods, p. 338

BAE. Other Aquods that have a mean annual soil temperature of 8° C or higher and mean summer and mean winter soil temperatures at a depth of 50 cm that differ by <5° C.

Tropaquods, p. 339

BAF. Other Aquods that have in >50 percent of each pedon a spodic horizon in which some subhorizon has a ratio of free iron (by dithionite-citrate) to carbon (both elemental) that is <0.2.

Haplaquods, p. 336

BAG. Other Aquods.

Sideraquods, p. 338

[1] If a placic horizon, duripan, or fragipan is present, the soil need not be saturated below that horizon.

Ferrods

This suborder is provisional. Ferrods are not known to occur in the United States, but the suborder is provided for use elsewhere. The classification has not been developed.

Ferrods are the Spodosols that

1. Have a spodic horizon that has in all subhorizons a ratio of percentage of free iron (by dithionite-citrate) to percentage of carbon (both elemental) of 6 or more; and
2. Do not have an aquic moisture regime or artificial drainage or do not have the characteristics associated with wetness as defined for Aquods.

Humods

Key to great groups

BCA. Humods that have a placic horizon in the spodic horizon.
Placohumods, p. 342

BCB. Other Humods that have an isomesic or warmer iso temperature regime.
Tropohumods, p. 342

BCC. Other Humods that have a fragipan below the spodic horizon.
Fragihumods, p. 341

BCD. Other Humods that have a cryic temperature regime.
Cryohumods, p. 340

BCE. Other Humods.
Haplohumods, p. 341

Orthods

Key to great groups

BDA. Orthods that have a placic horizon in the spodic horizon.
Placorthods, p. 347

BDB. Other Orthods that have a fragipan below the spodic horizon.
Fragiorthods, p. 344

BDC. Other Orthods that have a cryic or pergelic temperature regime.
Cryorthods, p. 343

BDD. Other Orthods that have an isomesic or warmer iso temperature regime.
Troporthods, p. 347

BDE. Other Orthods.
Haplorthods, p. 345

Humults

Key to great groups

FBA. Humults that have a sombric horizon within 1 m of the soil surface.

Sombrihumults, p. 358

FBB. Other Humults that have an argillic horizon that has <10 percent weatherable minerals in the 20- to 200-micron fraction in the upper 50 cm and has a clay distribution such that the percentage of clay does not decrease from its maximum amount by >20 percent of that maximum within 1.5 m of the soil surface, or the layer in which the percentage of clay is less than the maximum shows skeletans on ped faces or has 5 percent or more plinthite by volume.

Palehumults, p. 357

FBC. Other Humults that have plinthite that forms a continuous phase or constitutes >50 percent of the volume of some subhorizon within 1.25 m of the soil surface.

Plinthohumults, p. 358

FBD. Other Humults that have mean summer and mean winter soil temperatures at a depth of 50 cm or at a lithic or a paralithic contact, whichever is shallower, that differ by <5° C.

Tropohumults, p. 358

FBE. Other Humults.

Haplohumults, p. 356

Udults

Key to great groups

FCA. Udults that have a fragipan in or below the argillic horizon.

Fragiudults, p. 360

FCB. Other Udults that have plinthite that forms a continuous phase or constitutes more than half the volume in some horizon within the upper 1.25 m of the soil.

Plinthudults, p. 366

FCC. Other Udults that have an argillic horizon that has <10 percent weatherable minerals in the 20- to 200-micron fraction in the upper 50 cm and have a clay distribution such that the percentage of clay does not decrease from its maximum amount by more than 20 percent of that maximum within 1.5 m of the soil surface, or the layer in which the percentage of clay is less than the maximum has skeletans on ped faces or has 5 percent or more plinthite by volume.

Paleudults, p. 364

FCD. Other Udults that have

1. An epipedon that has a color value, moist, of less than 4 in all parts; and
2. An argillic horizon that has a color value, dry, of less than 5 and not more than 1 unit higher than the value, moist.

Rhodudults, p. 367

FCE. Other Udults that have an isomesic or warmer iso temperature regime.

Tropudults, p. 367

FCF. Other Udults.

Hapludults, p. 362

Ustults

Key to great groups

FDA. Ustults that have plinthite that forms a continuous phase or constitutes more than half the volume in some subhorizon within 1.25 m of the soil surface.

Plinthustults, p. 371

FDB. Other Ustults that have an argillic horizon that has <10 percent weatherable minerals in the 20- to 200-micron fraction in its upper 50 cm and have a clay distribution with depth such that the percentage of clay does not decrease from its maximum amount by >20 percent of that maximum within 1.5 m of the soil surface, or the layer in which the percentage of clay is less than the maximum has skeletans on ped faces or has 5 percent or more plinthite by volume.

Paleustults, p. 371

Ultisols

Key to suborders

FA. Ultisols, either saturated with water at some time of year or artificially drained, that have characteristics associated with wetness, namely, mottles, iron-manganese concretions >2 mm in diameter, or chroma, moist, of 2 or less immediately below any Ap or A1 horizon that has a value, moist, of less than 3.5 when rubbed; and also one or more of the following:

1. Dominant chroma, moist, of 2 or less in coatings on the surface of peds and mottles within the peds, or dominant chroma of 2 or less in the matrix of the argillic horizon and mottles of higher chroma (if the hue is redder than 10YR because of parent materials that remain red after citrate-dithionite extraction, the requirement for low chroma is waived);
2. Chroma, moist, of 1 or less on surfaces of peds or in the matrix of the argillic horizon; or
3. Dominant hue of 2.5Y or 5Y in the matrix of the argillic horizon and distinct or prominent mottles and also a thermic or isothermic or warmer soil temperature regime.

Aquults, p. 351 84

FB. Other Ultisols that have either or both of the following characteristics:

1. Have 0.9 percent or more organic carbon in the upper 15 cm of the argillic horizon; or
2. Have 12 kg or more organic carbon in the soil per square meter to a depth of 1 m below the base of the mineral soil surface, exclusive of any O horizon that may be present.

Humults, p. 355 85

FC. Other Ultisols that have a udic moisture regime.

Udults, p. 360 85

FD. Other Ultisols that have an ustic moisture regime.

Ustults, p. 369 85

FE. Other Ultisols that have a xeric moisture regime.

Xerults, p. 372 86

Aquults

Key to great groups

FAA. Aquults that have plinthite that forms a continuous phase or constitutes more than half the matrix of some subhorizon within 1.25 m of the soil surface.

Plinthaquults, p. 354

FAB. Other Aquults that have a fragipan and, if there is 5 percent or more by volume of plinthite in some subhorizon, the upper boundary of the fragipan is within 1 m of the surface of the soil.

Fragiaquults, p. 352

FAC. Other Aquults that have an abrupt textural change between the ochric epipedon or the albic horizon and the argillic horizon and have slow hydraulic conductivity in the argillic horizon.

Albaquults, p. 351

FAD. Other Aquults that have a clay distribution such that the percentage of clay does not decrease from its maximum by as much as 20 percent of the maximum within a depth of 1.5 m from the soil surface, or the horizon in which the percentage of clay is less than the maximum has skeletans on ped faces or contains 5 percent or more plinthite by volume; and the upper 50 cm of the argillic horizon has <10 percent weatherable minerals in the 20- to 200-micron fraction.

Paleaquults, p. 353

FAE. Other Aquults that have an isomesic or warmer iso temperature regime.

Tropaquults, p. 355

FAF. Other Aquults that have an ochric epipedon.

Ochraquults, p. 352

FAG. Other Aquults that have an umbric or a mollic epipedon.

Umbraquults, p. 355

FDC. Other Ustults that have:
1. An epipedon that has a color value, moist, less than 4 in all parts; and
2. An argillic horizon that has a color value, dry, less than 5 and not more than 1 unit higher than the value, moist.

Rhodustults, p. 371

FDD. Other Ustults.

Haplustults, p. 369

Xerults

Key to great groups

FEA. Xerults that have an argillic horizon that has <10 percent weatherable minerals in the 20- to 200-micron fraction in its upper 50 cm and have a clay distribution such that the percentage of clay does not decrease from its maximum amount by >20 percent of that maximum within 1.5 m of the soil surface, or the layer in which the percentage of clay is less than the maximum has skeletans on ped faces or has 5 percent or more plinthite by volume.

Palexerults, p. 373

FEB. Other Xerults.

Haploxerults, p. 372

Vertisols

Key to suborders

DA. Vertisols that have a thermic or mesic soil temperature regime and, unless irrigated, have cracks that open and close once each year and remain open for 60 consecutive days or more in the 90 days following the summer solstice in more than 7 out of 10 years but that are closed for 60 consecutive days or more during the 90 days following the winter solstice.

Xererts, p. 381 87

DB. Other Vertisols that, unless irrigated, have in most years cracks that either remain open throughout the year or are closed for less than 60 consecutive days at a period when the soil temperature at a depth of 50 cm is continuously higher than 8° C.

Torrerts, p. 377 87

DC. Other Vertisols that have cracks that open and close one or more times during the year in most years but do not remain open for as many as 90 cumulative days in most years.

Uderts, p. 377 87

DD. Other Vertisols.

Usterts, p. 379 87

Torrerts

Torrerts are the Vertisols of arid climates. Their cracks may stay open throughout the year in most years, although they may be partially or largely filled with a soil mulch if the soil is moved by wind or animals. These soils may have a short rainy season. If the cracks close as a result of rains during a warm season, they remain closed for less than 60 consecutive days in most years.

Uderts

Key to great groups

DCA. Uderts that have a chroma, moist, of 1.5 or more dominant in the matrix of some subhorizon in the upper 30 cm in more than half of each pedon.

Chromuderts, p. 378

DCB. Other Uderts.

Pelluderts, p. 378

Usterts

Key to great groups

DDA. Usterts that have a chroma, moist, of 1.5 or more in some part of the matrix of the upper 30 cm in more than half of each pedon.

Chromusterts, p. 379

DDB. Other Usterts.

Pellusterts, p. 380

Xererts

Key to great groups

DAA. Xererts that have a dominant chroma, moist, of 1.5 or more in the matrix of some subhorizon in the upper 30 cm in more than half of each pedon.

Chromoxererts, p. 381

DAB. Other Xererts.

Pelloxererts, p. 382

APPENDIX

Extract of "Approved Amendments and Clarification of Definitions" (May 5, 1978)

p. *6* Diagnostic surface horizons: the epipedon, add a second paragraph to this section:"There can be only one epipedon formed in the mineral surface horizon(s) of a soil. However this epipedon may be overlain by organic materials including a histic epipedon. Otherwise one sequum may contain only one epipedon."

p. *8* Mollic epipedon, item 6, line 4 change to read:"the epipedon or the amounts of P_2O_5 soluble in citric acid decrease or increase irregularly with depth below the epipedon, or there are phosphate nodules within the epipedon."

p.*14* Summary of the limits of a spodic horizon, line 3, delete"ochric or".
Item 2, line 4, after "size" insert "or larger".
Item 3a, line 7, after "carbon" change to read "(elemental) extractable by pyrophosphate at pH 10 to percentage clay is at least 0.2".

p.*15* Cambic horizon, second last line, after "not" insert "solely".

p.*21* Albic horizon, 2nd paragraph add to the ends of sentences 2 and 3 (lines 4 and 6) "either dry or moist, or both".

p.*31* Ustic moisture regime, insert after "torric regimes)" in line 9 of paragraph 3,"unless it is moist in some or all parts for 90 consecutive days or more when the soil temperature at a depth of 50 cm is above 8^{o} C."

p.*32* Cryic, item 1, change lines 1 and 2 to read: "1. In mineral soils the mean summer soil temperture (June, July, and August in the northern hemisphere and December, January, and February in the southern hemisphere) at a depth of 50 cm or at a".

Vertisols

Key to suborders

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Xererts, p. 381 87

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p.35 Tonguing of albic materials, add a new paragraph after the first paragraph: "Tongues of albic materials may extend from the upper boundary of the argillic horizon into the argillic horizon or they may be at any depth within the argillic horizon. Animal burrows or root traces containing albic materials may intrude into argillic horizons but these are not considered to be tongues."

Interfingering of albic materials, after the first sentence in line 5 add: "The interfingering need not extend to the upper boundary of the argillic horizon."

p.37 Organic soil materials, add the following to item 2: "...except for materials in which the bulk density (at 1/3-bar water retention) in the fine earth fraction is less than 0.85 g/cc and the exchange complex is dominated by amorphous material or which contain 60 percent (by weight) or more of vitric pyroclastic material".

p.39 Marl, item 2, insert a period after "CO2" and delete the rest of the statement.

p.42 Definition of classes, FRAGMENTAL, line 2, insert "some of the" before "interstices".

SANDY, change definition to read:"Sandy.- The texture of the fine earth is a sand or a loamy sand that is coarser than very fine sand or loamy very fine sand respectively; rock fragments make up less than 35 percent by volume."

p.43 CINDERY, line 3; ashy-skeletal, line 2 after "cinders" insert "and pumice".

p.42 Clarification of footnote 1:
1. If the ratio of 15-bar water to clay is 0.6 or more in half or more of the control section, the percentage of clay is consideredto be 2.5 times the percentage of 15-bar water. (Note:The National Soils Laboratory suggests the percentage clay may be closer to 2.2 times the percentage 15-bar water).
2. Carbonates of clay size are not considered to be clay but are treated as silt in all particle-size classes.

p.*44* Control section, and item A, line 2, change semicolon to comma. Intended meaning is from surface to 36 cm or the items listed if above 36 cm. Item Cb1, last line, " ≥ " not " > ".

Footnote 4, insert a new sentence before the last sentence: "The lower boundary is determined using the same curve and is the depth at which the clay content is less than that of the minimum requirement for an argillic horizon." Note: This statement is incomplete. Many soils have weathered rock below them and clay content may or may not decrease appreciably with depth.

p.*52* Depth of soil, shallow, line 8 after "Note that lithic" insert "and paralithic". All paralithic subgroups are shallow by definition.

p.*59* Ultisols, item F1, line 2, change: "within" to "at".

Item F1a, line 4, after "moist" insert: "and the epipedon does not have a sandy or sandy-skeletal particle-size class throughout".

Item F1, line 2, after "35" insert " [5] " (footnote on page *61*).

p.*60* Ultisols, item F1b, line 3 change "deeper" to "deepest".

Mollisols, item G2, line 1, after " 50 " insert " [5] " (footnote on page *61*).

Item G2b, line 1, delete "a cambic" and substitute "no argillic or natric".

Item G3, last line, change "comma" to a "period" after depth; delete "and"; delete item G4.

p.*61* Inceptisols, change I2c to read: "c. In some subhorizons between 20 and 50 cm below the mineral soil surface have an n value of 0.7 or less, or if all subhorizons between these depths have an n value of at least 0.7, there is less than 8 percent clay."

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p.*61* At bottom of page insert the following footnote:
"[5] Base saturation by sum of cations of 35 percent is approximately equivalent to 50 percent by NH_4OAc for soils with a surplus of moisture at some season i.e. udic or xeric moisture regimes or moister but exclusive of moisture regimes borderline to ustic or aridic moisture regimes."

p.*63* Item HAG, line 3, after "conductivity" insert " [8] " (footnote).

At bottom of page insert the following footnote:
"[8] Hydraulic Conductivity refers to the rate of internal water movement under a unit potential gradient. In this text it means vertical saturated hydraulic conductivity. Slow and very slow rates refer to 4 to 10 and less than 4 cm per day respectively."

p.*64* HEG of Paleudalfs, item 4, add after "following": "in the argillic horizon": and to the end of item c add "or in some subhorizon." ("of the argillic horizon" in items a and b is redundant and should be deleted.)

HCD of Key to great groups (of Ustalfs), line 2, place a semicolon after "or" and delete from "have" to "requirements:". To item 1, line2, insert after "and", "the argillic horizon". Item 1b(3), line 2, after "5" insert "in at least the lower part of the horizon".

p.*65* HDE of Key to great groups (of Xeralfs), item 1b(2) line 3, insert after "both": "in at least the lower part of the argillic horizon;"

p.*72* Key to suborders (Inceptisols), in IA (Aquepts) item 1d, line 2, for "soil surface by a layer that" substitute "mineral soil surface by a cambic horizon or a subhorizon above a fragipan either of which has".

Key to great groups, item IBC (Hydrandepts) change to read: "IBC. Other Andepts that lack a placic horizon and that have clays.."

p.*77* Key to great groups (Udolls), to line 2 after"decrease by" add "as much as".

p.78 Key to great groups (Ustolls), item GFC 1. line 2, insert before "20", "as much as".

Amend line 1 of item GFD to read: "GFD. Other Ustolls that do not have an argillic horizon above a calcic, gypsic, or petrocalcic horizon, and that have a calcic or gypsic horizon that has its ..".

Item GDC, 1., line 2, before "20" insert "as much as".

p.81 Key to great groups (Orthox), item CEC,1., line 3, insert after "extractable": "bases plus extractable" aluminium.

p.85 Key to great groups (Udults), FCC,line 1, insert after "Other Udults": "that do not have a lithic or a paralithic contact within 1.5 m of the mineral soil surface and".

Extract of "Approved Amendments MTSC-Note" No.1, 2 and 3 (1980) and memorandums of Director Soils of SCS, USDA, dated March 13 and June 12, 1981.

p.*45* Strongly contrasting particle-size classes, paragraph 2, add the following strongly contrasting particle-size classes: "Cindery over medial"
"Cindery over medial-skeletal"
"Ashy over medial".

p.*58* Vertisols, item D, line 1, delete: "have a mean annual soil temperature of $8^{o}C$ or higher and".

p.*59* Aridisols, item E1b, delete the word "either" and substitute the phrase: "have an aridic moisture regime, or". Delete all of items E1b(1) and E1b(2).

p.*61* Inceptisols, item I, replace all of item I with the following:

I. Other soils that have no sulfidic material within 50 cm of the mineral soil surface; and have between 20 and 50 cm below the mineral soil surface an $\underline{n}$ value of 0.7 or less in one or more subhorizon(s) or less than 8 percent clay in one or more subhorizons; and have one or more of the following:

1. An umbric, mollic, histic (either mineral or organic) or plaggen epipedon;
2. A cambic horizon or both an aquic moisture regime and permafrost;
3. Within 1 m of the surface, a calcic, petrocalcic, gypsic, petrogypsic, or placic horizon or a duripan;
4. A fragipan;
5. A sulfuric horizon whose upper boundary is within 50 cm of the soil surface; or
6. In half or more of the upper 50 cm, an SAR of $\geq$ 13[4] (or sodium satura-

tion that is $\geq$ 15 percent) that decreases with depth below 50 cm and, within a depth of 1 m, have ground water at some period during the year when the soil is not frozen in any part.

Inceptisols, p.227 *61*

p.*87* Key to suborders (Vertisols), item DA, line 1, change to read: "Vertisols that have a thermic, mesic, or frigid soil temperature ...".

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