

Bottom Tier

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

Thus, if the organic materials are thick, there are two possible thicknesses of the control section, depending on the presence or absence and the thickness of a surface mantle of fibric moss or other organic material that has a low bulk density (less than 0.1 g/cm³). If the fibric moss extends to a depth of 60 cm and is the dominant material within this depth (three-fourths or more of the volume), the control section is 160 cm thick. If the fibric moss is thin or absent, the control section extends to a depth of 130 cm.

Horizons and Characteristics Diagnostic for Both Mineral and Organic Soils

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

Aquic Conditions

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

Elements of aquic conditions are as follows:

1. Saturation is characterized by zero or positive pressure in the soil water and can generally be determined by observing free water in an unlined auger hole. Problems may arise, however, in clayey soils with peds, where an unlined auger hole may fill with water flowing along faces of peds while the soil matrix is and remains unsaturated (bypass flow). Such free water may incorrectly suggest the presence of a water table, while the actual water table occurs at greater depth. Use of well-sealed piezometers or tensiometers is therefore recommended for measuring saturation. Problems may still occur, however, if water runs into piezometer slits near the bottom of the piezometer hole or if tensiometers with slowly reacting manometers are used. The first problem can be overcome by using piezometers with smaller slits and the second by using

transducer tensiometry, which reacts faster than manometers. Soils are considered wet if they have pressure heads greater than -1 kPa. Only macropores, such as cracks between peds or channels, are then filled with air, while the soil matrix is usually still saturated. Obviously, exact measurements of the wet state can be obtained only with tensiometers. For operational purposes, the use of piezometers is recommended as a standard method.

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

Three types of saturation are defined:

- a. *Endosaturation*.—The soil is saturated with water in all layers from the upper boundary of saturation to a depth of 200 cm or more from the mineral soil surface.
- b. *Episaturation*.—The soil is saturated with water in one or more layers within 200 cm of the mineral soil surface and also has one or more unsaturated layers, with an upper boundary above a depth of 200 cm, below the saturated layer. The zone of saturation, i.e., the water table, is perched on top of a relatively impermeable layer.
- c. *Anthic saturation*.—This term refers to a special kind of aquic condition that occurs in soils that are cultivated and irrigated (flood irrigation). Soils with anthraquic conditions must meet the requirements for aquic conditions and in addition have *both* of the following:

- (1) A tilled surface layer and a directly underlying slowly permeable layer that has, for 3 months or more in normal years, *both*:
 - (a) Saturation and reduction; *and*
 - (b) Chroma of 2 or less in the matrix; *and*
- (2) A subsurface horizon with *one or more* of the following:
 - (a) Redox depletions with a color value of 4 or more, moist, and chroma of 2 or less in macropores; *or*
 - (b) Redox concentrations of iron and/or manganese; *or*
 - (c) 2 times or more the amount of iron (extractable by dithionite-citrate) than is contained in the tilled surface layer.

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

features that are identified in the keys. A simple field test is available to determine if reduced iron ions are present. A freshly broken surface of a field-wet soil sample is treated with alpha,alpha-dipyridyl in neutral, 1N ammonium acetate solution. The appearance of a strong red color on the freshly broken surface indicates the presence of reduced iron ions (i.e., Fe²⁺). A positive reaction to the alpha,alpha-dipyridyl field test for ferrous iron (Childs, 1981) may be used to confirm the existence of reducing conditions and is especially useful in situations where, despite saturation, normal morphological indicators of such conditions are either absent or obscured (as by the dark colors characteristic of melanic great groups). A negative reaction, however, does not imply that reducing conditions are always absent. It may only mean that the level of free iron in the soil is below the sensitivity limit of the test or that the soil is in an oxidized phase at the time of testing. For soils with very low levels of iron, the use of a field test such as Indicator of Reduction in Soils (IRIS) tubes painted with ferric iron may be warranted in order to document reducing conditions. Use of alpha,alpha-dipyridyl in a 10 percent solution of acetic acid is not recommended because the acid is likely to change soil conditions, for example, by dissolving CaCO₃.

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

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

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

(1) Nodules and concretions, which are cemented bodies that can be removed from the soil intact. Concretions are distinguished from nodules on the basis of internal organization. A concretion typically has concentric layers that are visible to the naked eye. Nodules do not have visible organized internal structure. Boundaries

commonly are diffuse if formed *in situ* and sharp after pedoturbation. Sharp boundaries may be relict features in some soils; *and*

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

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

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

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

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

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

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

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

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

Cryoturbation

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

Densic Contact

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

Keys to Soil Taxonomy

By Soil Survey Staff

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