Diagnostic horizons, properties and materials

Soil horizons, properties and materials are intended to reflect features which are widely recognized as occurring in soils and which can be used to describe and define soil classes. They are considered to be "diagnostic" when they reach a minimum degree of expression, which is determined by appearance, measurability, importance, relevance and quantitative criteria. To be considered diagnostic, soil horizons also require a minimum thickness, which must be appraised in relation to bioclimatic factors (e.g. an albic horizon in boreal regions is not expected to be as thick as one in the tropics).

The diagnostic horizons, properties and materials are described, where possible, giving a general description, the diagnostic criteria, possibilities for field identification and additional characteristics. Some relationships with other important diagnostic horizons are also given.

The cation exchange capacity (CEC), used as a criterion in the definition of diagnostic horizons or properties as well as in the key to the reference soil groups, is essentially meant to reflect the nature of the mineral component of the exchange complex. However, the CEC determined on the total earth fraction is also influenced by the amount and kind of organic matter present. Where low clay activity is a diagnostic property, it may be desirable to deduct CEC linked to the organic matter, using a graphical method[1] for individual profiles (Bennema and Camargo, 1979; Brinkman, 1979; Klamt and Sombroek, 1988).

The terminology used to describe soil morphology is that adopted in the *Guidelines for Soil Profile Description* (FAO, 1990). Colour notations are according to the *Munsell Soil Color Charts* (KIC, 1990). Chemical and physical characteristics are expressed on the basis of the methods given in the *Procedures for Soil Analysis* (Van Reeuwijk, 1995).

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1. The method involves regressing the amount of organic C (expressed in g) against the measured CEC (pH 7) expressed in $cmol_c\ kg^{-1}$ clay. With the resultant equation the contribution of the organic C to the CEC can be calculated, and the corrected CEC of the clay be determined. Uniform clay mineralogy throughout the profile should be assumed.

Diagnostic horizons

For WRB purposes the diagnostic horizons, defined in Revised Legend (FAO, 1988), have been used as a basis, with the exception of the *fimic* horizon which has not been retained. New ones are introduced, such as andic, anthropedogenic (anthraquic, hydragric, hortic, irragric, plaggic and terric horizons), chernic, cryic, duric, ferric, folic, fragic, fulvic, melanic, nitic, petroduric, petroplinthic, plinthic, salic, takyric, vertic, vitric and yermic horizons. Some of these horizons replace FAO's diagnostic properties and phases.

Albic horizon

General description. The albic horizon (from L. albus, white) is a light coloured subsurface horizon from which clay and free iron oxides have been removed, or in which the oxides have been segregated to the extent that the colour of the horizon is determined by the colour of the sand and silt particles rather than by coatings on these particles. It generally has a weakly expressed soil structure or lacks structural development altogether. The upper and lower boundaries are normally abrupt or clear. The morphology of the boundaries is variable and sometimes associated with albeluvic tonguing. Albic horizons usually have coarser textures than the overlying or underlying horizons, although this difference with respect to an underlying spodic horizon may only be slight. Many albic horizons are associated with wetness and contain evidence of gleyic or stagnic properties.

Diagnostic criteria. An albic horizon must have:

1. Munsell colour, dry:
   a. value of 7 or 8 and a chroma of 3 or less; **or**
   b. value of 5 or 6 and a chroma of 2 or less; **and**
2. Munsell colour, moist:
   - a value 6, 7 or 8 with a chroma of 4 or less; **or**
   - a value of 5 and a chroma of 3 or less; **or**
   - a value of 4 and a chroma of 2 or less[1]. A chroma of 3 is permitted if the parent materials have a hue of 5YR or redder, and the chroma is due to the colour of uncoated silt or sand grains; **and**
3. thickness: at least 1 cm.

Field identification. Identification of albic horizons in the field is based on Munsell soil colours. In addition to the colour determination, checks can be made using a x10 hand-lens to verify if coatings on sand and silt-sized particles are absent.

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1. Colour requirements have been slightly changed with respect to those defined in FAO (1988) and Soil Survey Staff (1996) to accommodate albic horizons, which show a considerable shift in chroma upon moistening. Such albic horizons occur frequently in, for example, the southern African region.

Additional characteristics. The presence of coatings around sand and silt grains can be determined using an optical microscope for analysing thin sections. Uncoated grains usually show a very thin rim at their surface. Coatings may be of an organic nature, consist of iron oxides, or both, and are dark coloured under translucent light. Iron coatings become reddish in colour under reflected light, while organic coatings remain brownish-black.

Relationships with some other diagnostic horizons. Albic horizons are normally overlain by humus-enriched surface horizons (mollic, umbric or ochric horizons) but may be at the surface due to erosion or artificial removal of the surface layer. They can be considered as an extreme type of eluvial horizon, and usually occur in association with illuvial horizons such as an argic, natric or spodic horizon, which they overlie. In sandy materials albic horizons can reach considerable thickness, up to several metres, especially in humid tropical regions, and associated diagnostic horizons may be hard to establish.

Andic horizon

General description. The andic horizon (from Japanese An, dark, and Do, soil) is a horizon resulting from moderate weathering of mainly pyroclastic deposits. However, they may also be found in association with non-volcanic materials (e.g. loess, argilites and ferralitic weathering products). Their mineralogy is dominated by short-range-order minerals, and they are part of the weathering sequence in pyroclastic deposits (tephric soil material > vitric horizon > andic horizon).

Andic horizons may be found both at the surface and in the subsurface. They also often occur as layers, separated by non-andic layers. As a surface horizon, andic horizons generally contain a high amount of organic matter (more than 5 percent), are very dark coloured (Munsell value and chroma, moist, is 3 or less), have a fluffy macrostructure and often a smeary consistence. They are light in weight (have a low bulk density), and have mostly silt loam or finer textures. Andic surface horizons rich in organic matter may be very deep, reaching often a thickness of 50 cm or more (pachic characteristic). Andic subsurface horizons are generally somewhat lighter coloured.

Andic horizons may have different properties, depending on the type of dominant weathering process acting upon the soil material. They may exhibit thixotropy, i.e. the soil material changes, under pressure or by rubbing, from a plastic solid into a liquified stage and back into the solid condition. In perhumid climates, humus-rich andic horizons may contain more than 100 percent water (by volume) compared to their oven-dry volume (hydric characteristic).

Two major types of andic horizons are recognized, one in which allophane and similar minerals are predominant (the *silandic* type), and one in which aluminium complexed by organic acids prevails (the *aluandic* type). The silandic horizon has an acid to neutral soil reaction, while the aluandic horizon varies from extremely acid to acid.

Diagnostic criteria. An andic horizon must have the following physical, chemical and mineralogical properties (Shoji et al, 1996; Berding, 1997):

1. bulk density of the soil at field capacity (no prior drying) of less than 0.9 kg dm^{-3}; **and**
2. 10 percent or more clay and an Al_{ox} + ½Fe_{ox}[1] value in the fine earth fraction of 2 percent op more; **and**
3. phosphate retention of 70 percent or more; **and**
4. volcanic glass content in the fine earth fraction of less than 10 percent; **and**
5. thickness of at least 30 cm.

Silandic horizons have an acid oxalate (pH 3) extractable silica (Si_{ox}) of 0.6 percent or more while alu-andic horizons have a Si_{ox} of less than 0.6 percent (or, alternatively, an Al_{py}[2]/Al_{ox} ratio of less than 0.5 and 0.5 or more, respectively).

Field identification. Andic horizons may be identified using the pH NaF field test developed by Fieldes and Perrott (1966). A pH NaF of more than 9.5 indicates an abundant presence of allophanic products and/or organo-aluminium complexes. The test is indicative for most andic horizons, except for those very rich in organic matter. However, the same reaction occurs in spodic horizons and in certain acid clayey soils, which are rich in aluminium interlayered clay minerals.

Silandic horizons generally have a field $pH_{(H2O)}$ of 5 or higher, while aluandic horizons mainly have a field $pH_{(H2O)}$ of less than 4.5. If the $pH_{(H2O)}$ is between 4.5 and 5, additional tests may be necessary to establish the 'alu-' or 'sili-' characteristic of the andic horizon.

Relationships with some other diagnostic horizons. Vitric horizons are distinguished from andic horizons by their lesser rate of weathering. This is evidenced by a higher volcanic glass content in vitric horizons (>10 percent of the fine earth fraction) and a lower amount of non-crystalline or paracrystalline pedogenetic minerals, as characterized by the moderate amount of acid oxalate (pH 3) extractable

1. Al_{ox} and Fe_{ox} are acid oxalate extractable aluminium and iron, respectively (method of Blakemore *et al*., 1987).
2. Al_{py}: pyrophosphate extractable aluminium.

aluminium and iron in vitric horizons (Al_{ox} + ½Fe_{ox} = 0.4-2.0 percent), by a higher bulk density (BD of vitric horizons is between 0.9 and 1.2 kg dm^{-3}), and by a lower phosphate retention (25-<70 percent).

To separate andic horizons rich in organic matter from histic and folic horizons, andic horizons are not permitted to contain more than 20 percent organic carbon, while histic horizons with an organic carbon content between 12 and 20 percent are not permitted to have properties associated with andic horizons.

Spodic horizons, which also contain complexes of sesquioxides and organic substances, can have similar characteristics to andic horizons rich in alumino-organic complexes. Sometimes only analytical tests can discriminate between the two. Spodic horizons have at least twice as much Al_{ox} + ½Fe_{ox} than an overlying umbric, ochric or albic horizon. This normally does not apply to andic horizons in which the alumino-organic complexes are virtually immobile.

Anthraquic horizons (see Anthropedogenic horizons)

Anthropedogenic horizons

General description. Anthropedogenic horizons (from Gr. anthropos, human, and pedogenesis) comprise a variety of surface and subsurface horizons which result from long-continued cultivation. The characteristics and properties of these horizons depend much on the soil management practices used (see Table 1). Anthropedogenic horizons differ from anthropogenic soil materials, which are unconsolidated mineral or organic materials resulting largely from land fills, mine spoil, urban fill, garbage dumps, dredgings, etc., produced by human activities. These materials, however, have **not** been subject to a sufficiently long period of time to have received significant imprint of pedogenetic processes.

Table 1: Anthropedogenic processes

Deep working	Continuous mechanical operations extending below normal depth of field operations
Intensive fertilization	Continuous applications of organic/inorganic fertilizers **without** substantial additions of mineral matter (e.g. manures, kitchen refuse, compost, night soil, etc.)
Extraneous additions	Continuous applications of earthy materials involving substantial additions of mineral matter (e.g. sods, beach sand, earthy manures, etc.)
Irrigation	Continuous applications of irrigation water **with** substantial amounts of sediments (may also include fertilizers, soluble salts, organic matter, etc.)
Wet cultivation	Processes associated with submergence during cultivation; puddling of cultivation layer; usually involving changes in aquic conditions. Diagnostic subsoil features, such as illuvial iron-manganese coatings, may develop under wet cultivation, depending on depth of water table, texture, presence of organic matter, etc.

The anthropedogenic horizons distinguished are the terric, irragric, plaggic, hortic, anthraquic and hydragric horizons. They occur over small areas in many parts of the world, notably on the old arable lands in western Europe, in the old irrigated plains in the Near East and China, in the old terraced land-scapes in the Mediterranean region and the Arab peninsula, and in isolated spots in North and South America associated with long-continued Indian occupation, as well as in areas where paddy rice has been cultivated for a long time.

Diagnostic criteria. A terric horizon (from L. terra, earth) develops through addition of earthy manures, compost or mud over a long period of time. It has a non-uniform textural differentiation with depth. Its colour is related to the source material or the underlying substrate. Base saturation (in 1 *M* NH_4OAc at pH 7.0) is more than 50 percent.

An **irragric** horizon (from L. irrigare, to irrigate, and agricolare, to cultivate) is a light coloured (Munsell colour value and chroma, moist, is more than 3), uniformly structured surface layer, devel-oped through long-continued irrigation with sediment-rich water. Clay and carbonates are evenly distributed and the irrgric horizon has more clay, particularly fine clay, than the underlying soil material. The weighted average organic carbon content exceeds 0.5 percent, decreasing with depth but remaining at least 0.3 percent at the lower limit of the irragric horizon.

A **plaggic** horizon (from Dutch *plag*, sod) has a uniform texture, usually sand or loamy sand. The weighted average organic carbon content is more than 0.6 percent. The base saturation (in 1 *M* NH_4OAc at pH 7.0) is less than 50 percent while the P_2O_5 content extractable in 1 percent citric acid is high, at least more than 0.25 percent within 20 cm of the surface, but frequently more than 1 percent.

A **hortic** horizon (from L. hortus, garden) results from deep cultivation, intensive fertilization and/or long-continued application of human and animal wastes and other organic residues. It is a dark coloured horizon with Munsell colour value and chroma (moist) of 3 or less. It has a weighted average organic carbon content of 1 percent or more, and 0.5 M $NaHCO_3$[1] extractable P_2O_5 content is more than 100 mg kg^{-1} fine earth in the upper 25 cm (Gong et al., 1997). Base saturation (in 1 *M* NH_4OAc at pH 7.0) is 50 percent or more.

An **anthraquic** horizon (from Gr. anthropos, human, and L. aqua, water) comprises a *puddled layer* and a *plough pan*. Characteristically, the plough pan has a platy structure. It is compacted and has a very low infiltration rate. It shows yellowish-brown, brown or reddish-brown rust mottles along cracks and root holes. The bulk density of the plough pan is at least 20 percent (relative) higher than that of the puddled layer, whereas its porosity is 10 to 30 percent (relative) lower than the porosity in the puddled layer. The non-capillary porosity is 2 to 5 percent.

A **hydragric** horizon (from Gr. hydros, water, and L. agricolare, to cultivate) is a subsurface horizon associated with wet cultivation with one or more of the following characteristics:

* Iron-manganese accumulation or illuvial Fe and Mn coatings; **or**
* dithionite-citrate extractable iron is 2 times or more, or dithionite-citrate extractable manganese is 4 times or more that of the surface horizon(s); **or**
* Redoximorphic features associated with wet cultivation; **and**
* Thickness of more than 10 cm.

Field identification. The **terric**, **irragric** and **plaggic** horizons all show evidence of surface raising, which may be inferred either from field observation or from historical records. The horizons are thoroughly mixed and usually contain artifacts such as pottery fragments, cultural debris or refuse, which are often very small (less than 1 cm in diameter) and much abraded. The terric and plaggic horizons are built up gradually from earthy additions (compost, sods or soddy materials mixed with farmyard manure, litter, mud, beach sands, etc.) and may contain stones, randomly sorted and distributed, while the irragric horizon is built up gradually from irrigation deposits.

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1. Known as the Olsen routine method (Olsen *et al*., 1954).

Few soil characteristics differentiate the terric and plaggic horizons from each other. Terric horizons usually show a high biological activity, have a neutral to slightly alkaline soil reaction (pH (H_2O) is normally more than 7.0), and may contain free lime. The colour is strongly related to the source material or the underlying substrate. Buried soils may be observed at the base of the horizon although the contact can be obscured by mixing.

The **plaggic** horizon has brownish or blackish colours, related to the origin of source materials and its soil reaction is slightly to strongly acid. It shows evidence of agricultural operations such as spade marks as well as old cultivation layers. Plaggic horizons often overlie buried soils although the original surface layers may be mixed. The lower boundary is usually clear.

The **irragric** horizon shows evidence of considerable biological activity and has more than 25 percent earthworm casts by volume. The lower boundary is clear and irrigation deposits may be present below.

The **hortic** horizon is also thoroughly mixed and stratification, if present originally, is not preserved. Artifacts and cultural debris are common, but often much abraded. Earthworm casts take up more than 25 percent of the volume. Tillage marks or evidence of mixing of the soil can be present. Buried soils may be preserved but they are usually incorporated in the horizon.

The **anthraquic** horizon comprises the puddled layer and the plough pan of a soil under long continued paddy cultivation. The puddled layer has colours associated with reduction, accompanied by low hue mottles and Fe-Mn cutans on ped faces and pore walls. It is very dispersible, shows sorting of soil aggregates and has vesicular pores.

The **hydragric** horizon has either reduction features in pores such as coatings or halos with a colour hue of 2.5Y or yellower and a chroma (moist) of 2 or less, or segregations of iron and/or manganese in the matrix as a result of the oxidative environment. It usually shows grey clay-fine silt and clay-silt-humus cutans on ped faces.

Argic horizon

General description. The argic horizon (from L. argilla, white clay) is a subsurface horizon which has a distinctly higher clay content than the overlying horizon. The textural differentiation may be caused by an illuvial accumulation of clay, by predominant pedogenetic formation of clay in the subsoil or destruction of clay in the surface horizon, by selective surface erosion of clay, by biological activity, or by a combination of two or more of these different processes. Sedimentation of surface materials which are coarser than the subsurface horizon may enhance a pedogenetic textural differentiation. However, a mere lithological discontinuity, such as may occur in alluvial deposits, does not qualify as an argic horizon.

Soils with argic horizons often have a specific set of morphological, physico-chemical and mineralogical properties other than a mere clay increase. These properties allow various types of 'argic' horizons to be distinguished and to trace their pathways of development (Sombroek, 1986). Main subtypes are lixi-, luvi-, abrupti- and plan-argic horizons, and natric and nitic horizons.

The argic B horizon as defined in the Revised Legend of the Soil Map of the World (FAO, 1988) is taken as a reference, with one modification. The requirement to observe in the field *'... at least 1 percent clay skins on ped surfaces and in pores ...'* is changed into **5** percent. This change is based on the notion that there is no 1 : 1 correspondence between the amount of clay skins on ped surfaces and in pores, and the percentage of the thin section occupied by oriented clay. Even if 100 percent of the ped surfaces are covered by clay skins, the thin section will in its major part be occupied by the matrix of the soil and voids.

Diagnostic criteria. An argic horizon must have:

1. texture of sandy loam or finer and at least 8 percent clay in the fine earth fraction; **and**
2. more 'total' clay than an overlying coarser textured horizon (exclusive of differences which result from a lithological discontinuity only) such that:
   - if the overlying horizon has less than 15 percent 'total' clay in the fine earth fraction, the argic horizon must contain at least 3 percent more clay; **or**
   - if the overlying horizon has 15 percent or more and less than 40 percent 'total' clay in the fine earth fraction, the ratio of clay in the argic horizon to that of the overlying horizon must be 1.2 or more; **or**
   - if the overlying horizon has 40 percent or more 'total' clay in the fine earth fraction, the argic horizon must contain at least 8 percent more clay; **and**
3. a markedly increased clay content relative to the overlying horizon, within a vertical distance of 30 cm if the argic horizon is formed by clay illuviation or within a vertical distance of 15 cm in any other case; **and**
4. autochthonous rock structure is absent in at least half the volume of the horizon; **and**
5. thickness of at least one tenth of the sum of the thickness of all overlying horizons and at least 7.5 cm thick. If the argic horizon is entirely composed of lamellae, the lamellae must have a combined thickness of at least 15 cm. The coarser textured horizon overlying the argic horizon must be at least 18 cm thick or 5 cm if the textural transition to the argic horizon is abrupt (see abrupt textural change).

Field identification. Textural differentiation is the main feature for recognition of argic horizons in the field. The illuvial nature may be established in the field using a x10 hand-lens if clear clay skins occur on ped surfaces, in fissures, in pores and in channels. An 'illuvial' argic horizon should at least in some part show clay skins on at least 5 percent of both horizontal and vertical ped faces and in the pores.

Clay skins are often difficult to detect in soils with a smectitic mineralogy as these are destroyed regularly by shrink-swell movements. The presence of clay skins in 'protected' positions, e.g. in pores, should be sufficient to meet the requirements for an 'illuvial' argic horizon.

Additional characteristics. The illuvial character of an argic horizon can best be established using thin sections. Diagnostic 'illuvial' argic horizons must show areas with oriented clays that constitute on average at least 1 percent of the entire cross-section. Other tests involved are particle size distribution analysis, to determine the increase in clay content over a specified depth, and the fine clay[1]/total clay analysis. In 'illuvial' argic horizons the fine clay/total clay ratio is larger than in the overlying horizons, caused by preferential eluviation of fine clay particles.

If the soil shows a **lithological discontinuity** over or within the argic horizon, or if the surface horizon has been removed by erosion, or if only a plough layer overlies the argic horizon, the illuvial nature must be clearly established.

A lithological discontinuity, if not clear from the field (data), can be identified by the percentage of coarse sand, fine sand and silt, calculated on a clay-free basis (international particle size distribution or using the additional groupings of the USDA system or other), or by changes in the content of gravel and coarser fractions. A change of at least 20 percent (relative) of any of the major particle size fractions can be regarded as diagnostic for a lithological discontinuity. However, it should only be taken into account if it is located in the section of the profile where the clay increase occurs and if there is evidence that the overlying layer was coarser textured.

Although this is a simplified way of treating lithological discontinuities, not much more can be done with the data commonly available. On the other hand, particle size discontinuities are of main interest for the argic horizon and will show if the overlying material was very much different and coarser, even without considering clay loss due to eluviation or other processes.

Relationships with some other diagnostic horizons. Argic horizons are normally associated with and situated below eluvial horizons, i.e. horizons from which clay and iron have been removed. Although initially formed as a subsurface horizon, argic horizons may occur at the surface as a result of erosion or removal of the overlying horizons.

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1. Fine clay: <0.2 µm.

Some clay-increase horizons may have the set of properties which characterize the ferralic horizon, i.e. a low CEC and ECEC (effective CEC), a low content of water-dispersible clay and a low content of weatherable minerals, all over a depth of 50 cm. In such cases a ferralic horizon has preference over an argic horizon for classification purposes. However, an argic horizon prevails if it overlies a ferralic horizon and it has, in its upper part over a depth of 30 cm, 10 percent or more water-dispersible clay, unless the soil material has geric properties or more than 1.4 percent organic carbon.

Argic horizons also lack the structure and sodium saturation characteristics of the natric horizon.

Calcic horizon

General description. The calcic horizon (from L. calxis, lime) is a horizon in which secondary calcium carbonate ($CaCO_3$) has accumulated either in a *diffuse form* (calcium carbonate present only in the form of fine particles of 1 mm or less, dispersed in the matrix) or as *discontinuous concentrations* (pseudomycelia, cutans, soft and hard nodules, or veins). The accumulation may be in the parent material, or in subsurface horizons, but it can also occur in surface horizons as a result of erosion. If the accumulation of soft carbonates becomes such that all or most of the pedological and/or lithological structures disappear and *continuous concentrations* of calcium carbonate prevail, the horizon is named a hypercalcic horizon (from Gr. hyper, superseding, and L. calxis, lime).

Diagnostic criteria. A calcic horizon must:
1. show evidence of secondary carbonates accumulation, **and**
2. have calcium carbonate equivalent content in the fine earth fraction of 15 percent or more (for *hypercalcic horizons* more than 50percent calcium carbonate equivalent in the fine earth fraction); **and**
3. have a thickness of 15 cm or more.

Field identification. The presence of calcium carbonate can be identified in the field using a 10% HCl solution. The degree of effervescence (audible only, visible as individual bubbles, or foam-like) is an indication of the amount of lime present. This test is important if only diffuse distributions are present.

Other indications for the presence of a calcic or hypercalcic horizon are:

1. soil colours which are more or less white, pinkish to reddish, or grey; and
2. a low porosity (inter-aggregate porosity in the (hyper-)calcic horizon is usually less than that in the horizon immediately above and possibly also less than in the horizon directly underneath).

Calcium carbonate content may decrease with depth, but this is often difficult to establish, particularly if the calcic horizon occurs in the deeper subsoil. Accumulation of secondary lime is therefore sufficient to diagnose a (hyper-)calcic horizon.

Additional characteristics. Determination of the amount of calcium carbonate (by weight) and the changes within the soil profile of the calcium carbonate content are the main analytical criteria for establishing the presence of a calcic horizon. Determination of the pH (H_2O) enables distinction between accumulations with a basic ('calcic') character (pH 8.0 - 8.7) due to the dominance of $CaCO_3$, and those with an ultrabasic ('non-calcic') character (pH > 8.7) because of the presence of $MgCO_3$ or Na_2CO_3.

In addition, microscopical analysis of thin sections may reveal the presence of dissolution forms in horizons above or below a calcic horizon, evidence of silicate epigenesis (isomorphous substitution of quartz by calcite), or the presence of other calcium carbonate accumulation structures, while clay mineralogical analyses of calcic horizons often show clays characteristic of confined environments, such as montmorillonites, attapulgites and sepiolites.

Relationships with some other diagnostic horizons. When hypercalcic horizons become indurated, transition takes place to the petrocalcic horizon, the expression of which may be massive or as platy structures.

In dry regions and in the presence of sulphate-bearing soil- or groundwater solutions, calcic horizons occur associated with gypsic horizons. Calcic and gypsic horizons usually occupy different positions in the soil profile because of the difference in solubility of calcium carbonate and gypsum, and normally they can be clearly distinguished from each other by the difference in morphology. Gypsum crystals tend to be needle-shaped, often visible with the naked eye, whereas pedogenetic calcium carbonate crystals are much finer in size.

Cambic horizon

General description. The cambic horizon (from L. cambiare, to change) is a subsurface horizon showing evidence of alteration relative to the underlying horizons. It lacks the set of properties diagnostic for a ferralic, argic, natric or spodic horizon and the dark colours, organic matter content and structure of a histic, folic, mollic or umbric horizon.

Diagnostic criteria. A cambic horizon must have:

1. texture in the fine earth fraction of sandy loam or finer; **and**
2. soil structure which is at least moderately developed or autochthonous rock structure is absent in at least half the volume of the horizon; **and**
3. evidence of alteration in one or more of the following forms:
   - stronger chroma, redder hue, or higher clay content than the underlying horizon; **or**
   - evidence of removal of carbonates. A cambic horizon always has less carbonate than an underlying horizon with calcium carbonate accumulation. However, not all primary carbonates have to be leached from a horizon in order for it to qualify as a cambic horizon. If all coarse fragments in the underlying horizon are completely coated with lime, some of these fragments in the cambic horizon are partly free of coatings. If the coarse fragments in the horizon showing calcium carbonate accumulation are coated only on the underside, those in the cambic horizon should be free of coatings; **or**
   - 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 absence of rock structure; **and**
4. **not** have the brittle consistence (moist) typical for the fragic horizon; **and**
5. - a cation exchange capacity (in 1 *M* NH_4OAc) of more than 16 cmol(+) kg^{-1} clay; **or**
   - an effective cation exchange capacity (sum of exchangeable bases plus exchangeable acidity in 1 *M* KCl) of 12 cmol(+) kg^{-1} clay or more; **or**
   - a content of 10 percent or more weatherable minerals in the 50-200 µm fraction[1]; **or**
   - 10 percent or more water-dispersible clay; **and**;

6. thickness of at least 15 cm, with the base of the horizon at least 25 cm below the soil surface.

Relationships with some other diagnostic horizons. The cation exchange capacity/effective cation exchange capacity/weatherable mineral requirements set the cambic horizon apart from the ferralic horizon.

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1. Instead of analysing the weatherable mineral content, this requirement may be replaced by the analysis of the total reserve in bases (TRB = exchangeable plus mineral Ca, Mg, K and Na). A TRB of 25 $cmol_c\ kg^{-1}$ soil correlates well with an amount of 10 percent weatherable minerals in the 50-200 µm fraction.

Chernic horizon

General description. The chernic horizon (from Russian chern, black) is a special type of mollic horizon. It is a deep, well structured, blackish surface horizon with a high base saturation, a high content in organic matter and a high biological activity.

Diagnostic criteria. A chernic horizon must have:

1. granular or fine subangular blocky soil structure; **and**
2. both broken and crushed samples with a Munsell chroma of less than 2.0 when moist, a value darker than 2.0 when moist and 3.0 when dry. If there is more than 40 percent finely divided lime, or if the texture of the horizon is loamy sand or coarser, the limits of colour value dry are waived; the colour value, moist, should be 3 or less. The colour value must be at least one unit darker than that of the C-horizon[1] (both moist and dry), unless the soil is derived from dark coloured parent material, in which case the colour contrast requirement is waived. If a C-horizon is not present, comparison should be made with the horizon immediately underlying the surface horizon. The above colour requirements apply to the upper 15 cm of the chernic horizon, or immediately below any plough layer; **and**
3. 50 percent or more (by volume) of the horizon consisting of wormholes, wormcasts, and filled animal burrows; **and**
4. an organic carbon content of at least 1.5 percent (2.5 percent organic matter) throughout the thickness of mixed soil. The organic carbon content is at least 6 percent if the colour requirements are waived because of finely divided lime, or 1.5 percent more than the Chorizon if the colour requirements are waived because of dark coloured parent materials; **and**
5. a base saturation (in 1 *M* NH_4OAc at pH 7.0) of 80 percent or more; **and**
6. thickness of at least 35 cm. The measurement of the thickness of a chernic horizon includes transitional horizons in which the characteristics of the surface horizon are dominant - for example, AB, AE or AC.

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1. Reference is made here to the master horizon nomenclature as used in FAO's *Guidelines for Soil Profile Description* (1990).

Field identification. The chernic horizon can be identified by its blackish colour, caused by the accumulation of organic matter, well developed structure (usually granular), high biological activity, mainly worms and other burrowing animals, and its thickness.

Relationships with some other diagnostic horizons. The special character of the chernic horizon with respect to the mollic horizon is expressed by its higher organic carbon content, the darker colours required, the high biological contribution to the soil structure, and its greater minimum depth. The upper limit of organic carbon content is 12 percent (20 percent organic matter) which is the lower limit for the histic horizon or 20 percent, the lower limit for a folic horizon.

Cryic horizon

General description. The cryic horizon (from Gr. kryos, cold, ice) is a perennially frozen soil horizon in *mineral* or *organic* soil materials.

Diagnostic criteria. A cryic horizon must have:

1. soil temperature at or below 0°C for two or more years in succession; **and**
2. - in the presence of sufficient interstitial soil water, evidence of cryoturbation, frost heave, cryogenic sorting, thermal cracking, or ice segregation; **or**
   - in the absence of sufficient interstitial soil moisture, evidence of thermal contraction of the frozen soil material; **and**
3. platy or blocky macrostructures resulting from vein ice development, and orbicular, conglomeratic and banded microstructures resulting from sorting of coarse soil material.

Field identification. If soil moisture is present, cryic horizons show evidence of perennial ice segregation and/or cryogenic processes (mixed soil material, disrupted soil horizons, involutions (swirl-like patterns in soil horizons), organic intrusions, frost heave, separation of coarse from fine soil materials, cracks, patterned surface features such as earth hummocks, frost mounds, stone circles, nets and polygons).

If insufficient interstitial soil water is present, the cryic horizons are dry but thermal contraction features occur, although more weakly developed than those in cryic horizons with a higher moist content.

Relationships with some other diagnostic horizons. Cryic horizons may bear characteristics of histic, andic or spodic horizons, and may occur in association with salic, calcic, mollic, umbric or ochric horizons. In cold arid regions yermic horizons may be found in association with cryic horizons.

Duric horizon

General description. The duric horizon (from L. durum, hard) is a subsurface horizon showing weakly cemented to indurated nodules cemented by silica (SiO_2), presumably in the form of opal and micro-crystalline forms of silica ("durinodes").

Diagnostic criteria. A duric horizon must :

1. have 10 percent or more (by volume) of durinodes with the following properties:
   - do not break down in concentrated hydrochloric acid (HCl), but break down in hot concentrated potassium hydroxide (KOH) after treatment with HCl; **and**
   - are firm or very firm, and brittle when wet, both before and after treatment with acid; **and**
   - have a diameter of 1 cm or more; **and**
2. have a thickness of 10 cm or more.

Additional characteristics. Dry durinodes do not slake appreciably in water, but prolonged soaking can result in spalling of very thin platelets and in some slaking. In cross-section most durinodes are roughly concentric, and concentric stringers of opal may be visible under a hand lens.

Relationships with some other diagnostic horizons. In arid regions duric horizons occur associated with gypsic, petrogypsic, calcic and petrocalcic horizons. In more humid climates the duric horizon may grade into fragic horizons.

Ferralic horizon

General description. The ferralic horizon (from L. ferrum, iron, and alumen, alum) is a subsurface horizon resulting from long and intense weathering, in which the clay fraction is dominated by low activity clays, and the silt and sand fractions by highly resistant minerals, such as iron-, aluminium-, manganese- and titanium oxides.

Diagnostic criteria. A ferralic horizon must have:

1. a sandy loam or finer particle size and less than 90 percent (by weight) gravel, stones or petroplinthic (iron-manganese) concretions; **and**
2. a cation exchange capacity (in 1 *M* NH_4OAc at pH 7.0) of 16 cmol(+) kg^{-1} clay or less and an effective cation exchange capacity (sum of exchangeable bases plus exchangeable acidity in 1 *M* KCl) of less than 12 cmol(+) kg^{-1} clay; **and**
3. less than 10 percent water-dispersible clay, unless the soil material has geric properties or more than 1.4 percent organic carbon; **and**
4. less than 10 percent weatherable minerals in the 50-200 µm fraction; **and**
5. no characteristics diagnostic for the andic horizon; **and**
6. thickness of at least 30 cm.

Field identification. Ferralic horizons are associated with old and stable geomorphic surfaces. Generally, the macrostructure seems to be moderate to weak at first sight. However, typical ferralic horizons have a strong microaggregation ('pseudosand'). The consistence is usually friable, which gives the appearance as if 'the soil material flows like flour between the fingers'. Hand specimens of ferralic horizons are usually relatively light in weight because of the low bulk density. Indicative of the high porosity is the hollow sound many ferralic horizons produce when tapped.

Illuviation and stress features such as clay skins and pressure faces are generally lacking, although some illuviation cutans may occur in the lower part of the horizon. Boundaries of a ferralic horizon are normally diffuse and little differentiation in colour or particle size distribution within the horizon can be detected. It has a texture that is sandy loam or finer in the fine earth fraction and has less than 90 percent (by weight) gravel, stones or petroplinthic concretions.

Additional characteristics. As an alternative to the weatherable minerals requirement, a total reserve of bases (TRB = exchangeable plus mineral Ca, Mg, K and Na) of less than 25 cmol(+) kg^{-1} soil may be indicative.

Relationships with some other diagnostic horizons. Ferralic horizons may meet the clay increase requirements which characterize the argic horizon. If the upper 30 cm of the clay-increase horizon contains 10% or more water-dispersible clay, an argic horizon has preference over a ferralic horizon for classification purposes, unless the soil material has geric properties or more than 1.4 percent organic carbon.

Acid ammonium oxalate (pH 3) extractable Fe, Al and Si (Al_{ox}, Fe_{ox}, Si_{ox}) in ferralic horizons is very low, which sets it apart from the andic and nitic horizons. Andic horizons have at least $Al_{ox} + ½Fe_{ox} > 0.4$ (in the presence of more than 10 percent volcanic glass particles in the fine earth fraction), and nitic horizons have a significant amount of active iron oxides: more than 0.2 percent acid oxalate (pH 3) extractable iron from the fine earth fraction which, in addition, is more than 5 percent of the citrate-dithionite extractable iron.

The limit with the cambic horizon is formed by the cation exchange capacity/effective cation exchange capacity/weatherable mineral requirements. Some cambic horizons have a low cation exchange capacity; however, the amount of weatherable minerals (or, alternatively, the total reserve in bases) is too high for a ferralic horizon. Such horizons represent an advanced stage of weathering and form the transition between the cambic and the ferralic horizon.

Ferric horizon

General description. The ferric horizon (from L. ferrum, iron) is a horizon in which segregation of iron has taken place to such an extent that large mottles or concretions have formed and the inter-mottle/ inter-concretionary matrix is largely depleted of iron. Generally, such segregation leads to poor aggregation of the soil particles in iron-depleted areas and compaction of the horizon.

Diagnostic criteria. A ferric horizon must have:

1. many (more than 15 percent of the exposed surface area) coarse mottles with hues redder than 7.5YR and chroma more than 5, or both; **or**
2. discrete nodules, up to 2 cm in diameter, the exteriors of the nodules being enriched and weakly cemented or indurated with iron and having redder hues or stronger chroma than the interiors; **and**
3. thickness of at least 15 cm.

Relationships with some other diagnostic horizons. If the amount of nodules reaches 10 percent or more (by volume) and the nodules harden irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying with free access of oxygen, the horizon is considered to be a plinthic horizon. Therefore, ferric horizons may, in tropical or subtropical regions, grade laterally into plinthic horizons. The transition between the two is often not very clear.

Folic horizon

General description. The folic horizon (from L. folium, leaf) is a surface horizon, or a subsurface horizon occurring at shallow depth, which consists of well-aerated organic soil material.

Diagnostic criteria. A folic horizon must have:

1. more than 20 percent (by weight) organic carbon (35 percent organic matter); **and**
2. water saturation for less than one month in most years; **and**
3. thickness of more than 10 cm. If a folic horizon is less than 20 cm thick, the upper 20 cm of the soil after mixing must contain 20 percent or more organic carbon.

Relationships with some other diagnostic horizons. Histic horizons have similar characteristics to the folic horizon; however, these are saturated with water for one month or more in most years. Moreover, the composition of the histic horizon is generally different from that of the folic horizon as the vegetative cover is often different.

Fragic horizon

General description. The fragic horizon (from L. fragilis, frangere, to break) is a natural non-cemented subsurface horizon with a pedality and a porosity pattern such that roots and percolating water penetrate the soil only along interped faces and streaks. The natural character excludes plough pans and surface traffic pans.

Diagnostic criteria. A fragic horizon must have:

1. higher bulk density relative to the horizons above; **and**
2. less than 0.5 percent organic carbon; **and**
3. penetration resistance more than 50 kN m^{-2}; **and**
4. slaking or fracturing of an air-dry clod within 10 minutes when placed in water; **and**
5. no cementation upon repeated wetting and drying; **and**
6. thickness of at least 25 cm.

Field identification. A fragic horizon has a prismatic and/or blocky structure. The inner parts of the peds can have a relative high total porosity, including pores larger than 200 mm, but as a result of a dense outer rim of the peds no continuity exists between the inped pores and the interped pores and fissures. The fragic horizon is devoid of active faunal burrowing activity, except occasionally along the interped streaks. As a result of this 'closed box system', more than 90 percent of the soil volume cannot be explored by the root systems and is isolated from percolating water. An estimate or measurement of this soil volume can only be made by combining both vertical and horizontal sections of the fragic horizon.

The ped interface or streak can have the colour, mineralogical and chemical characteristics of an eluvial or albic horizon, or meet the requirements of albeluvic tonguing. In the presence of a fluctuating water table this part of the soil is depleted of iron and manganese. As air remains trapped inside the peds, a concomitant iron accumulation is observed at the level of the ped surface and manganese accumulations will occur further inside the peds (*stagnic colour pattern*).

Fragic horizons are commonly loamy, but loamy sand and clay textures are not excluded. In the latter case the clay mineralogy is dominantly kaolinitic.

Dry clods are hard to extremely hard, moist clods are firm to extremely firm, and moist consistence can be brittle. A ped or clod from a fragic horizon tends to rupture suddenly rather than to undergo slow deformation when pressure is applied.

Relationships with some other diagnostic horizons. A fragic horizon may underlie, although not necessarily directly, an albic, cambic, spodic or argic horizon, unless the soil has been truncated. It can overlap partly or completely with an argic horizon. Laterally, fragic horizons may grade into (petro-)duric horizons in dry regions. Moreover, fragic horizons can have stagnic properties.

Fulvic horizon

General description. The fulvic horizon (from L. fulvus, dark yellow) is a thick, black horizon at or near to the surface, which is usually associated with short-range-order minerals (usually allophane) or with organo-aluminium complexes. It has a low bulk density and contains a high amount of organic matter.

Diagnostic criteria. A fulvic horizon must have:

1. properties characteristic for andic horizons throughout its thickness; **and**
2. a Munsell colour value (moist) and chroma of 2 or less; **and**
3. a melanic index[1] of more than 1.7 throughout; **and**
4. a weighted average of 6 percent or more organic carbon, and 4 percent or more organic carbon in all parts; **and**
5. cumulative thickness of at least 30 cm with less than 10 cm "non-fulvic" material in between.

Field identification. The intense dark colour, its thickness, as well as its usual association with pyroclastic deposits makes the fulvic horizon easy recognizable in the field. However, distinction between the fulvic and melanic horizon can only be made after laboratory analyses.

1. See Honna *et al.* (1988).

Gypsic horizon

General description. The gypsic horizon (from L. gypsum) is a non-cemented horizon containing secondary accumulations of gypsum ($CaSO_4.2H_2O$) in various forms.

Diagnostic criteria. A gypsic horizon must have:

1. 15 percent or more gypsum; if the horizon contains 60 percent or more gypsum, it becomes a *hypergypsic horizon* (from Gr. hyper, superseding, and L. gypsum). The percentage gypsum is calculated as the product of gypsum content, expressed as cmol(+) kg^{-1} soil, and the equivalent weight of gypsum (i.e. 86) expressed as a percentage; **and**
2. thickness of at least 15 cm, also for hypergypsic horizons.

Field identification. Gypsum may be found in the form of pseudomycelia, as coarse-sized crystals (individualized, as nests, beards or coatings, or as elongated groupings of fibrous crystals) or as compact powdery accumulations. The latter form gives the gypsic horizon a massive structure and a sandy texture. The distinction between compact powdery accumulations and the others is important in terms of soil potentiality.

Gypsic horizons can be associated with calcic horizons but occur always in separate positions within the soil profile, because of the higher solubility of gypsum with respect to lime.

Additional characteristics. Determination of the amount of gypsum in the soil to verify the required content and increase, as well as thin section analysis, are helpful to establish the presence of a gypsic horizon and the distribution of the gypsum in the soil mass.

Relationships with some other diagnostic horizons. When hypergypsic horizons become indurated, transition takes place to the petrogypsic horizon, the expression of which may be as massive or platy structures.

In dry regions gypsic horizons are associated with calcic or salic horizons. Calcic and gypsic horizons usually occupy distinct positions in the soil profile as the solubility of calcium carbonate is different from that of gypsum. They normally can be clearly distinguished from each other by the morphology (see calcic horizon). Salic and gypsic horizons also occupy different positions for the same reasons.

Histic horizon

General description. The histic horizon (from Gr. histos, tissue) is a surface horizon, or a subsurface horizon occurring at shallow depth, which consists of poorly aerated organic soil material.

Diagnostic criteria. A histic horizon must have:

1. - 18 percent (by weight) organic carbon (30 percent organic matter) or more if the mineral fraction comprises 60 percent or more clay; **or**
   - 12 percent (by weight) organic carbon (20 percent organic matter) or more if the mineral fraction has no clay; **or**
   - a proportional lower limit of organic carbon content between 12 and 18 percent if the clay content of the mineral fraction is between 0 and 60 percent. If present in materials characteristic for andic horizons, the organic carbon content must be more than 20percent (35 percent organic matter); **and**
2. saturation with water for at least one month in most years (unless artificially drained); **and**
3. thickness of 10 cm or more. A histic horizon less than 20 cm thick must have 12 percent or more organic carbon when mixed to a depth of 20 cm.

Hydragric horizon (see Anthropedogenic horizons)

Hortic horizon **(see Anthropedogenic horizons)**

ANNEXES

DIAGNOSTIC HORIZONS

Irragric horizon (see Anthropedogenic horizons)

Melanic horizon

General description. The melanic horizon (from Gr. melanos, black) is a thick, black horizon at or near to the surface, which is usually associated with short-range-order minerals (usually allophane) or with organo-aluminium complexes. It has a low bulk density and contains a high amount of organic matter of a type which is thought to result from large amounts of root residues supplied by a graminaceous vegetation.

Diagnostic criteria. A melanic horizon must have:

1. properties and characteristic for andic horizons throughout its thickness; **and**
2. a Munsell colour value (moist) and chroma of 2 or less; **and**
3. a melanic index[1] of 1.70 or less throughout; **and**
4. a weighted average of 6 percent or more organic carbon, and 4 percent or more organic carbon in all parts; **and**
5. cumulative thickness of at least 30 cm with less than 10 cm "non-melanic" material in between.

Field identification. The intense dark colour, its thickness, as well as its usual association with pyroclastic deposits makes the melanic horizon easy to recognize in the field. The relationship with grassland vegetation can only be established under natural conditions, otherwise it may be inferred from historical records. However, laboratory analyses to determine the type of organic matter may be necessary to identify unambiguously the melanic horizon.

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1. See Honna *et al.* (1988).

Mollic horizons

General description. The mollic horizon (from L. mollis, soft) is a well structured, dark coloured surface horizon with a high base saturation and a moderate to high content in organic matter.

Diagnostic criteria. A mollic horizon must have:

1. soil structure sufficiently strong that the horizon is not both massive and hard or very hard when dry. Very coarse prisms (prisms larger than 30 cm in diameter) are included in the meaning of massive if there is no secondary structure within the prisms; **and**
2. both broken and crushed samples have a Munsell chroma of less than 3.5 when moist, a value darker than 3.5 when moist and 5.5 when dry. If there is more than 40 percent finely divided lime, the limits of colour value dry are waived; the colour value, moist, should be 5 or less. The colour value must be at least one unit darker than that of the C-horizon (both moist and dry), unless the soil is derived from dark coloured parent material, in which case the colour contrast requirement is waived. If a C-horizon is not present, comparison should be made with the horizon immedeate-ly underlying the surface horizon; **and**
3. an organic carbon content of 0.6 percent (1 percent organic matter) or more throughout the thickness of mixed horizon. The organic carbon content is at least 2.5 percent if the colour requirements are waived because of finely divided lime, or 0.6 percent more than the C-horizon if the colour requirements are waived because of dark coloured parent materials; **and**
4. a base saturation (in 1 *M* NH_4OAc at pH 7.0) of 50 percent or more on a weighted average throughout the depth of the horizon; **and**
5. the following thickness:
   - 10 cm or more if resting directly on hard rock, a petrocalcic, petroduric or petrogypsic horizon, or overlying a cryic horizon or material containing more than 40 percent $CaCO_3$; **or**
   - at least 20 cm and more than one-third of the thickness of the solum where the solum is less than 75 cm thick; **or**

- more than 25 cm where the solum is more than 75 cm thick.

The measurement of the thickness of a mollic horizon includes transitional horizons in which the characteristics of the surface horizon are dominant - for example, AB, AE or AC. The requirements for a mollic horizon must be met after the first 20 cm are mixed, as in ploughing.

Field identification. A mollic horizon can easily be identified by its dark colour, caused by the accumulation of organic matter, well developed structure (usually a granular or fine subangular blocky structure), an indication for high base saturation, and its thickness.

Relationships with some other diagnostic horizons. The base saturation of 50 percent separates the mollic horizon from the umbric horizon, which is otherwise similar. The upper limit of organic carbon content varies from 12 percent (20 percent organic matter) to 18 percent organic carbon (30 percent organic matter) which is the lower limit for the histic horizon or 20 percent, the lower limit for a folic horizon.

A special type of mollic horizon is the chernic horizon. It has a higher organic carbon content (1.5 per-cent or more), a specific structure (granular or fine subangular blocky), a very dark colour in its upper part, a high biological activity, and a minimum thickness of 35 cm.

Limits with high base-saturated fulvic and melanic horizons are set by the combination of the intense dark colour, the high organic carbon content, the thickness and the characteristics associated with andic horizons in these two horizons. Otherwise mollic horizons frequently occur in association with andic horizons.

Natric horizon

General description. The natric horizon (from Dutch natrium, sodium) is a dense subsurface horizon with a higher clay content than the overlying horizon(s). The increase in clay content between the natric horizon and the overlying horizon must meet the same requirements as an argic horizon. Moreover, it has a high content in exchangeable sodium and/or magnesium.

Diagnostic criteria. A natric horizon must have:

1. texture of sandy loam or finer and at least 8 percent clay in the fine earth fraction; **and**
2. more total clay than an overlying coarser textured horizon (exclusive of differences which result from a lithological discontinuity only) such that:
   - if the overlying horizon has less than 15 percent total clay in the fine earth fraction, the natric horizon must contain at least 3 percent more clay; **or**
   - if the overlying horizon has 15 percent or more and less than 40 percent total clay in the fine earth fraction, the ratio of clay in the natric horizon to that of the overlying horizon must be 1.2 or more; **or**
   - if the overlying horizon has 40 percent or more total clay in the fine earth fraction, the natric horizon must contain at least 8 percent more clay; **and**
3. an increase in clay content within a vertical distance of 30 cm if a natric horizon is formed by clay illuviation. In any other case the increase in clay content between the overlying and the natric horizon must be reached within a vertical distance of 15 cm; **and**
4. rock structure is absent in at least half the volume of the horizon; **and**
5. a columnar or prismatic structure in some part of the horizon, or a blocky structure with tongues of an eluvial horizon in which there are uncoated silt or sand grains, extending more than 2.5 cm into the horizon; **and**
6. an exchangeable sodium percentage (ESP[1]) of more than 15 within the upper 40 cm, or more exchangeable magnesium plus sodium than calcium plus exchange acidity (at pH 8.2) within the same depth if the saturation with exchangeable sodium is more than 15 percent in some subhorizon

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1. ESP = exchangeable Na x 100 / CEC.

within 200 cm of the surface; **and**

7. thickness of at least one tenth of the sum of the thickness of all overlying horizons and at least 7.5 cm thick.

A coarser textured horizon overlying the natric horizon must be at least 18 cm thick or 5 cm if the textural transition to the natric horizon is abrupt (see abrupt textural change).

Field identification. The colour of the natric horizon ranges from brown to black, especially in the upper part. The structure is coarse columnar or prismatic, sometimes blocky, or may even be massive. Rounded and often whitish coloured tops of the structural elements are characteristic.

Both colour and structural characteristics depend on the composition of the exchangeable cations and the soluble salt content in the underlying layers. Often thick and dark coloured clay cutans or other plasma separations occur, especially in the upper part of the horizon. Natric horizons have a poor aggregate stability and very low permeability under wet conditions. When dry the natric horizon becomes hard to extremely hard. Soil reaction is strongly alkaline; $pH_{(H2O)}$ is more than 8.5.

Additional characteristics. Natric horizons are characterized by a high $pH_{(H2O)}$ which is frequently more than 9.0. Another measure to characterize the natric horizon is the sodium adsorption ratio (SAR) which has to be 13 cmol(+)/l or more. The SAR is calculated from soil solution data:

$SAR = Na^{+} / [(Ca^{2+} + Mg^{2+}) / 2]^{0.5}$ cmol(+)/l

Micromorphologically, natric horizons show a specific fabric. The peptized plasma shows a strong orientation in a mosaic or parallel striated pattern. The plasma separations also show a high content in associated humus. Microcrusts, cutans, papules and infillings appear, when the natric horizon is impermeable.

Relationships with some other diagnostic horizons. A surface horizon usually rich in organic matter overlies the natric horizon. This horizon of humus accumulation varies in thickness from a few centimetres to more than 25 cm, and may be a mollic or ochric horizon. An albic horizon may be present between the surface and the natric horizon.

Frequently, a salt-affected layer occurs below the natric horizon. The salt influence may extend into the natric horizon which besides being sodic then also becomes saline. Salts present may be chlorides, sulphates or (bi-)carbonates.

Nitic horizon

General description. The nitic horizon (from L. nitidus, shiny) is a clay-rich subsurface horizon with as its main feature a moderately to strongly developed polyhedric or nutty structure with many shiny ped faces, which cannot or can only partially be attributed to clay illuviation.

Diagnostic criteria. A nitic horizon must have:

1. diffuse to gradual transitions to horizons immediately above and below (less than 20 percent change in clay content, over at least 12 cm; no abrupt colour change); **and**
2. - more than 30 percent clay; **and**
   - water-dispersible clay/total clay ratio less than 0.10 (unless there is more than 0.6 percent organic carbon); **and**
   - silt/clay ratio is less than 0.40; **and**
3. moderate to strong, nutty or polyhedric structure, with many shiny pedfaces, which cannot or can only partially be associated with illuviation argillans in thin sections; **and**
4. no gleyic or stagnic properties; **and**
5. - 4.0 percent or more citrate-dithionite extractable iron ("free" iron) in the fine earth fraction; **and**
   - more than 0.20 percent acid oxalate (pH 3) extractable iron ("active" iron) in the fine earth fraction; **and**
   - ratio between "active" and "free" iron of 0.05 or more; **and**
6. minimum thickness of 30 cm, with gradual to diffuse transitions to horizons immediately above and below the nitic horizon.

Field identification. A nitic horizon has a clay loam or finer texture, although the material feels loamy. The change in clay content with the overlying and underlying horizons is gradual. The colours are of low value and chroma with hues often 2.5YR, but sometimes redder or yellower. There is no abrupt colour change with the horizons above and below. Mottling indicative of a hydromorphic nature is lacking. The structure is moderate to strong angular blocky which easily falls apart into flat edged or nut-shaped elements showing shiny ped faces which are either thin clay coatings or pressure faces.

Nitic horizons often contain magnetic minerals such as maghemite. Presence of such minerals can be tested using a magnet.

Additional characteristics. The cation exchange capacity (in 1 *M* NH_4OAc at pH 7.0), corrected for organic matter, is less than 36 cmol(+) kg^{-1} clay, and often below 24 cmol(+) kg^{-1} clay. The effective cation exchange capacity (sum of exchangeable bases plus exchangeable acidity in 1 *M* KCl) is about half of the CEC. The moderate to low CEC and ECEC reflect the dominance of 1:1 lattice clays being both kaolinite and (meta-)halloysite.

Relationships with some other diagnostic horizons. The nitic horizon may be considered as a special type of argic horizon, or a strongly expressed cambic horizon, with specific properties such as a low amount of water dispersible clay and a high amount of "active" iron. As such the nitic horizon has preference over both for classification purposes. Its mineralogy (kaolinitic/(meta-)halloysitic) sets it apart from most vertic horizons which have dominantly a smectitic mineralogy. However, laterally nitic horizons may grade into vertic horizons occurring in lower landscape positions. The well expressed soil structure, the high amount of "active" iron, and often medium cation exchange capacity in nitic horizons sets them apart from ferralic horizons.

Ochric horizon

General description. The ochric horizon (from Gr. ochros, pale) is a surface horizon lacking fine stratification and which is either light coloured[1], or thin, or has an low organic carbon content, or is massive and (very) hard when dry.

Diagnostic criteria. An ochric horizon lacks fine stratification and has one (or more) of the following characteristics or properties:

1. both massive and hard or very hard when dry. Very coarse prisms (prisms larger than 30cm in diameter) are included in the meaning of massive if there is no secondary structure within the prisms; **or**
2. both broken and crushed samples have a Munsell chroma of 3.5 or more when moist, a value of 3.5 or more when moist and 5.5 or more when dry. If there is more than 40 percent finely divided lime, the colour value, moist, should be more than 5; **or**
3. an organic carbon content of less than 0.6 percent (1 percent organic matter) throughout the thickness of mixed horizon. The organic carbon content must be less than 2.5 percent if there is more than 40 percent finely divided lime; **or**
4. thickness of:
   - less than 10 cm if resting directly on hard rock, a petrocalcic, petroduric or petrogypsic horizon, or overlying a cryic horizon; **or**
   - less than 20 cm or less than one-third of the thickness of the solum where the solum is less than 75 cm thick; **or**
   - 25 cm or less where the solum is more than 75 cm thick.

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1. In arid and semi-arid environments ochric horizons occur which have a light or bleached colour (commonly grey) when dry which turns darker on moistening ("bleached surface horizons"). They do not qualify for an albic horizon because of the colour requirements in both dry and moist state. They are characterized by low (usually <0.4%; South African results) organic carbon and free iron oxide contents. They are coarse textured, show signs of the development of a platy structure and the presence of a thin surface crust. In Australia it is known as bleached A horizon (Northcote, 1979), while in South Africa (Soil Classification Working Group, 1991) it is defined on the second (family) level of classification as a bleached (orthic) Ahorizon. The bleached surface horizon has many negative influences on soil use. Its low physical stability causes the subsoil to remain relatively dry after most rain events. As a result emergence of plant seeds does not readily take place. This is further enhanced by the platy structure and crust formation. In arid regions this phenomenon can lead to large areas without plant coverage (barren land), which are highly susceptible to soil erosion.

Relationships with some other diagnostic horizons. Ochric horizons have direct linkages with mollic or umbric horizons. The absence of fine stratification sets an ochric horizon apart from unaltered recent sediments.

Petrocalcic horizon

General description. A petrocalcic horizon (from Gr. petros, rock, and L. calxis, lime) is an indurated calcic horizon, which is cemented by calcium carbonate and, in places, by calcium and some magnesium carbonate. It is either massive or platy in nature, and extremely hard.

Diagnostic criteria. A petrocalcic horizon must have:

1. a calcium carbonate equivalent of 50 percent (by weight) or more; **and**
2. cementation to the extent that dry fragments do not slake in water and roots cannot enter; **and**
3. extremely hard consistence when dry so that it cannot be penetrated by spade or auger; **and**
4. thickness of at least 10 cm, or 2.5 cm if it is laminar and rests directly on bedrock.

Field identification. Petrocalcic horizons occur as *non-platy calcrete*, either massive or nodular in nature, or as *platy calcrete*, of which the following types are the most frequent:

- *lamellar calcrete*: superimposed separate petrified layers varying in thickness from a few millimetres to several centimetres. The colour is generally white or pink.
- *petrified lamellar calcrete*: one or several extremely hard layers, having grey or, more often, pink colours. They are generally more cemented than the lamellar calcrete and the internal organization is very massive (no fine lamellar structures, but coarse lamellar structures may be present).

Non-capillary pores in petrocalcic horizons are filled, and the hydraulic conductivity is moderately slow to very slow.

Relationships with some other diagnostic horizons. In arid regions petrocalcic horizons may occur in association with (petro-)duric horizons in which it may laterally grade. Petrocalcic and duric horizons are differentiated by the cementing agent. In petrocalcic horizons calcium and some magnesium carbonate constitutes the main cementing agent while some accessory silica may be present. In duric horizons silica is the main cementing agent, with or without calcium carbonate. Petrocalcic horizons also occur in association with gypsic, hypergypsic, or petrogypsic horizons. Associated surface horizons are usually ochric horizons.

Petroduric horizon

General description. The petroduric horizon (from Gr. petros, rock, and L. durum, hard), also known as duripan, is a subsurface horizon, usually reddish or reddish brown in colour, which is cemented mainly by secondary silica (SiO_2, presumably opal and microcrystalline forms of silica). Air-dry fragments of petroduric horizons do not slake in water, even after prolonged wetting. Calcium carbonate may be present as accessory cementing agent. It is either massive, or has a platy or laminar structure.

Diagnostic criteria. A petroduric horizon must have:

1. cementation or induration in more than 50 percent of some subhorizon; **and**
2. evidence of silica accumulation (opal or other forms of silica) e.g. as coatings in some pores, on some structural faces or as bridges between sand grains; **and**
3. less than 50 percent of the volume slaking in 1 *M* HCl even after prolonged soaking, but more than 50 percent slaking in concentrated KOH or in alternating acid and alkali; **and**
4. a lateral continuity such that roots cannot penetrate except along vertical fractures, which have a horizontal spacing of 10 cm or more; **and**
5. thickness of 10 cm or more.

Field identification. A petroduric horizon has a very to extremely firm consistence when moist, and is very or extremely hard when dry. Effervescence after applying 10% HCl may take place, but is probably not as vigorous as in petrocalcic horizons which look very similar. However, they may occur in conjunction with a petrocalcic horizon.

Relationships with other diagnostic horizons. In dry and arid climates petroduric horizons may grade laterally into petrocalcic horizons, and/or occur in conjunction with calcic or gypsic horizons which it normally overlies. In more humid climates petroduric horizons may grade laterally into fragic horizons.

Petrogypsic horizon

General description. The petrogypsic horizon (from Gr. petros, rock, and L. gypsum) is a cemented horizon containing secondary accumulations of gypsum ($CaSO_4.2H_2O$).

Diagnostic criteria. A petrogypsic horizon must have:

1. 60 percent or more gypsum. The percentage gypsum is calculated as the product of gypsum content, expressed as cmol(+) kg^{-1} soil, and the equivalent weight of gypsum (86) expressed as a percentage; **and**
2. cementation to the extent that dry fragments do not slake in water and it cannot be penetrated by roots; **and**
3. thickness of 10 cm or more.

Field identification. Petrogypsic horizons are whitish hard materials which contain dominantly gypsum. Sometimes, extremely hard and old petrogypsic horizons are capped by a thin laminar layer of about 1 cm thick.

Additional characteristics. Determination of the amount of gypsum in the soil to verify the required content and increase, as well as thin section analysis, are helpful techniques to establish the presence of a petrogypsic horizon and the distribution of the gypsum in the soil mass.

In thin sections the petrogypsic horizon shows a compacted microstructure with only a few cavities. The matrix is composed of densely packed lenticular gypsum crystals mixed with small amounts of detrital material. The matrix has a faint yellow colour in plain light. Irregular nodules formed by colourless transparent zones consist of coherent crystal aggregates with a hypidiotopic or xenotopic fabric and are mostly associated with (former) pores. Traces of biological activity (pedotubules) are sometimes visible.

Relationships with some other diagnostic horizons. As the petrogypsic horizon develops from a hypergypsic horizon, the two are closely linked. The degree of cementation distinguishes a petrogypsic from a hypergypsic horizon.

Petrogypsic horizons frequently occur associated with calcic horizons. Calcic and gypsic accumulations usually occupy different positions in the soil profile because the solubility of calcium carbonate is different fo that of gypsum. Normally they can be clearly distinguished from each other by their morphology (see calcic horizon).

Petroplinthic horizon

General description. The petroplinthic horizon (from Gr. petros, rock, and plinthos, brick) is a continuous layer of indurated material, in which iron is an important cement and in which organic matter is absent, or present only in traces.

Diagnostic criteria. A petroplinthic horizon must have:

1. - 10 percent (by weight) or more citrate-dithionite extractable iron, at least in the upper part of the horizon; **and**
   - ratio between acid oxalate (pH 3) extractable iron and citrate-dithionite extractable iron of less than 0.10[1]; **and**
2. less than 0.6 percent (by weight) organic carbon; **and**
3. cementation to the extent that dry fragments do not slake in water and it cannot be penetrated by roots; **and**
4. thickness of 10 cm or more.

Field identification. Petroplinthic horizons are extremely hard, usually rusty brown to yellowish brown coloured layers, which may be either massive, or show a reticulate or interconnected platy or columnar pattern, that encloses non-indurated material. They develop by irreversibly hardening of plinthite. The indurated layer may be fractured, but then the average lateral distances between the fractures must be 10 cm or more and the fractures themselves should not occupy more than 20 percent (by volume) of the layer.

Relationships with some other diagnostic horizons. Petroplinthic horizons are closely associated with plinthic horizons from which they develop. Often plinthic horizons can be traced by following petroplinthic layers which have formed, for example, in road cuts.

1. Estimated from data given by Varghese and Byju (1993).

The low organic matter content separates the petroplinthic horizon from thin iron pans, bog iron and indurated spodic horizons as occurring in, for instance, Podzols, which do contain a fair amount of organic matter.

Plaggic horizon **(see Anthropedogenic horizons)**

Plinthic horizon

General description. The plinthic horizon (from Gr. plinthos, brick) is a subsurface horizon which constitutes an iron-rich, humus-poor mixture of kaolinitic clay with quartz and other constituents, and which changes irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying with free access of oxygen.

Diagnostic criteria. The plinthic horizon must have:

1. 25 percent (by volume) or more of an iron-rich, humus-poor mixture of kaolinitic clay with quartz and other diluents, which changes irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying with free access of oxygen; **and**
2. - 2.5 percent (by weight) or more citrate-dithionite extractable iron in the fine earth fraction, especially in the upper part of the horizon, or 10 percent in the mottles or concretions; **and**
   - ratio between acid oxalate (pH 3) extractable iron and citrate-dithionite extractable iron of less than 0.10; **and**
3. less than 0.6 percent (by weight) organic carbon; **and**
4. a thickness of 15 cm or more.

Field identification. A plinthic horizon commonly shows red mottles, usually in platy, polygonal, vesicular or reticulate patterns. In a perennially moist soil, the plinthic material is usually not hard but firm or very firm and can be cut with a spade. The plinthic material does not harden irreversibly as a result of a single cycle of drying and rewetting. Only repeated wetting and drying will change it irreversibly to an ironstone hardpan or to irregular aggregates, especially if it is also exposed to heat from the sun.

Additional criteria. Micromorphological studies may reveal the extent of impregnation of the soil mass by iron. In addition penetration resistance measurements and total amount of iron present may give an indication.

Salic horizon

General description. The salic horizon (from L. sal, salt) is a surface or shallow subsurface horizon which contains a secondary enrichment of readily soluble salts, i.e. salts more soluble than gypsum ($CaSO_4.2H_2O$; log Ks = - 4.85 at 25°C).

Diagnostic criteria. A salic horizon must have, throughout its depth:

1. - an electrical conductivity (EC) of the saturation extract of more than 15 dS m^{-1} at 25°C at some time of the year; **or**
   - an EC of more than 8 dS m^{-1} at 25°C if the $pH_{(H2O)}$ of the saturation extract exceeds 8.5 (for alkaline carbonate soils) or less than 3.5 (for acid sulphate soils); **and**
2. product of thickness (in cm) times salt percentage of 60 or more; **and**
3. thickness of 15 cm or more.

Field identification. Circumstantial evidence usually points to the presence of a salic horizon. Halophyte vegetation like *Tamarix* and salt-tolerant crops are first indicators. Salt-affected layers often exhibit 'puffy' structures. Salts precipitate only after evaporation of the soil moisture. If the soil is moist or wet these precipitations need not to be present.

Salts may precipitate at the surface ('external Solonchaks') or at depth ('internal Solonchaks'). A salt crust at the surface is part of the salic horizon.

Spodic horizon

General description. The spodic horizon (from Gr. spodos, wood ash) is a dark coloured subsurface horizon which contains illuvial amorphous substances composed of organic matter and aluminium, with or without iron. The illuvial materials are characterized by a high pH-dependent charge, a large surface area and high water retention.

Diagnostic criteria. A spodic horizon must have:

1. - a Munsell hue of 7.5YR or redder with value of 5 or less and chroma of 4 or less when moist and crushed; **or**
   - a hue of 10YR with value of 3 or less and chroma of 2 or less when moist and crushed; **or**
   - a subhorizon which is 2.5 cm or more thick and which is continuously cemented by a combination of organic matter and aluminium, with or without iron ('thin iron pan'); **or**
   - distinct organic pellets between sand grains; **and**
2. 0.6 percent or more organic carbon; **and**
3. a soil-pH (1:1 in water) of 5.9 or less; **and**
4. - at least 0.50 percent Al_{ox} + ½Fe_{ox}[1] and have two times or more Al_{ox}+ ½Fe_{ox} than an overlying umbric, ochric, albic or anthropedogenic horizon; **or**
   - an ODOE-value (Optical Density of the Oxalate Extract) of 0.25 or more, which also is two times or more the value of the overlying horizons; **and**
5. thickness of at least 2.5 cm and an upper limit below 10 cm of the mineral soil surface, unless permafrost is present within 200 cm depth.

Field identification. A spodic horizon normally underlies an albic horizon and meets the brownish black to reddish brown colours. Spodic horizons can also be characterized by the presence of a thin iron pan, or by the presence of organic pellets when weakly developed.

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1. Al_{ox} and Fe_{ox}: acid oxalate (pH 3) extractable aluminium and iron, respectively.

Relationships with some other diagnostic horizons. Spodic horizons can have similar characteristics as andic horizons rich in alumino-organic complexes. Sometimes only analytical tests can positively discriminate between the two. Spodic horizons have at least twice as much the Al_{ox} + ½Fe_{ox} percentages than an overlying umbric, ochric, albic or anthropedogenic horizon. This criterion normally does not apply to andic horizons in which the alumino-organic complexes are hardly mobile.

Sulfuric horizon

General description. The sulfuric horizon (from L. sulfur) is an extremely acid subsurface horizon in which sulphuric acid is formed through oxidation of sulphides.

Diagnostic criteria. A sulfuric horizon must have:

1. a soil-pH < 3.5 in a 1:1 water suspension; **and**
2. - yellow/orange jarosite [$KFe_3(SO_4)_2(OH)_6$] or yellowish-brown schwertmannite [$Fe_{16}O_{16}(SO_4)_3(OH)_{10}.10H_2O$] mottles; **or**
   - concentrations with a Munsell hue of 2.5Y or more and a chroma of 6 or more; **or**
   - superposition on sulfidic soil materials; **or**
   - 0.05 percent (by weight) or more water-soluble sulphate; **and**
3. thickness of 15 cm or more.

Field identification. Sulfuric horizons generally contain yellow/orange jarosite or yellowish brown schwertmannite mottles. Moreover, soil reaction is extremely acid; pH (H_2O) of less than 3.5 is not uncommon.

Relationships with some other diagnostic horizons. The sulfuric horizon often underlies a strongly mottled horizon with pronounced redoximorphic features (reddish to reddish brown iron hydroxide mottles and a light coloured, iron depleted matrix).

Takyric horizon

General description. A takyric horizon (from Uzbek takyr, barren land) is a heavy textured surface horizon comprising a surface crust and a platy structured lower part. It occurs under arid conditions in periodically flooded soils.

Diagnostic criteria. A takyric horizon must have:

1. aridic properties; **and**
2. a platy or massive structure; **and**
3. a surface crust which has all of the following properties:
   - enough thickness (> 5 cm) so that it does not curl entirely upon drying; **and**
   - polygonal desiccation cracks extending at least 2 cm deep when the soil is dry; **and**
   - sandy clay loam, clay loam, silty clay loam or finer texture; **and**
   - very hard dry consistence and very plastic and sticky wet consistence.

Field identification. Takyric horizons are found in depressions in arid regions, where surface water, rich in clay and silt but relatively low in soluble salts, can accumulate and leach the upper soil horizons. Periodic salt leaching causes dispersion of clay and the formation of a thick, compact, fine-textured crust, which forms prominent polygonal cracks upon drying. Clay and silt often make up more than 80 percent of the crust material.

Relationships with some other diagnostic horizons. Takyric horizons occur in association with many diagnostic horizons, the most important ones being the salic, gypsic, calcic and cambic horizons. The low electrical conductivity and low soluble salt content of takyric horizons set them apart from the salic horizon.

Terric horizon **(see Anthropedogenic horizons)**

Umbric horizon

General characteristics. The umbric horizon (from L. umbra, shade) is a thick, dark coloured, base-desaturated surface horizon rich in organic matter.

Diagnostic criteria. An umbric horizon must have:

1. soil structure sufficiently strong that the horizon is not both massive and hard or very hard when dry. Very coarse prisms larger than 30 cm in diameter are included in the meaning of massive if there is no secondary structure within the prisms; **and**
2. Munsell colours with a chroma of less than 3.5 when moist, a value darker than 3.5 when moist and 5.5 when dry, both on broken and crushed samples. The colour value is at least one unit darker than that of the C-horizon (both moist and dry) unless the C-horizon has a colour value darker than 4.0, moist, in which case the colour contrast requirement is waived. If a c horizon is not present, comparison should be made with the horizon immediately underlying the surface horizon; **and**
3. base saturation (in 1 *M* NH_4OAc at pH 7.0) of less than 50 percent on a weighted average throughout the depth of the horizon; **and**
4. organic carbon content of 0.6 percent (1 percent organic matter) or more throughout the thickness of mixed horizon (usually it is more than 2 to 5 percent, depending on the clay content). The organic carbon content is at least 0.6 percent more than the C-horizon if the colour requirements are waived because of dark coloured parent materials; **and**
5. the following thickness requirements:
   - 10 cm or more if resting directly on hard rock, a petroplinthic or petroduric horizon, or overlying a cryic horizon; **or**
   - at least 20 cm and more than one-third of the thickness of the solum where the solum is less than 75 cm thick; **or**
   - more than 25 cm where the solum is more than 75 cm thick.

   The measurement of the thickness includes transitional AB, AE and AC horizons.

The requirements for an umbric horizon must be met after the first 20 cm are mixed, as in ploughing.

Field identification. The main field characteristics used to identify the presence of an umbric horizon are its dark colour and its structure. In general, umbric horizons tend to have a lesser grade of soil structure than mollic horizons.

As a guide, most umbric horizons have an acid soil reaction (pH (H_2O, 1:2.5) of less than about 5.5) which represents a base saturation of less than 50 percent. An additional indication for the acidity is a rooting pattern in which most of the roots tend to be horizontal, in the absence of a physical root restricting barrier.

Relationships with some other diagnostic horizons. The base saturation requirement sets the umbric horizon apart from the mollic horizon, which otherwise is very similar. The upper limit of organic carbon content varies from 12 percent (20 percent organic matter) to 18 percent (30 percent organic matter) which is the lower limit for the histic horizon, or 20 percent, the lower limit of a folic horizon.

Limits with base-desaturated fulvic and melanic horizons are set by the combination of the intense dark colour, the high organic carbon content, the thickness and the characteristics associated with andic horizons in these two horizons. Otherwise, umbric horizons frequently occur in association with andic horizons.

Some thick, dark coloured, organic-rich, base-desaturated surface horizons occur which are formed as a result of human activities such as deep cultivation and manuring, the addition of organic manures, the presence of ancient settlements, kitchen middens, etc. (cf. anthropedogenic horizons). These horizons can usually be recognized in the field by the presence of artifacts, spade marks, contrasting mineral inclusions or stratification indicating the intermittent addition of manurial material, a relative higher position in the landscape, or by checking the agricultural history of the area. If hortic or plaggic horizons are present, either the 0.5 *M* $NaHCO_3$ P_2O_5 analysis (Gong et al., 1997) or the 1 percent citric acid soluble P_2O_5 analysis may give an indication.

Vertic horizon

General description. The vertic horizon (from L. vertere, to turn) is a clayey subsurface horizon which as a result of shrinking and swelling has polished and grooved ped surfaces ('slickensides'), or wedge-shaped or parallelepiped structural aggregates.

Diagnostic criteria. A vertic horizon must have:

1. 30 percent or more clay throughout; **and**
2. wedge-shaped or parallelepiped structural aggregates with a longitudinal axis tilted between 10^{o} and 60^{o} from the horizontal; **and**
3. intersecting slickensides[1]; **and**
4. a thickness of 25 cm or more.

Field identification. Vertic horizons are clayey, and have a hard to very hard consistency. When dry, vertic horizons show cracks of 1 or more centimetre wide. In the field the presence of polished, shiny ped surfaces ("slickensides") which often show sharp angles with each other, is very obvious.

Additional characteristics. The coefficient of linear extensibility (COLE) is a measure for the shrink-swell potential and is defined as the ratio of the difference between the moist length and the dry length of a clod to its dry length: $(L_m-L_d)/L_d$, in which L_m is the length at 33 kPa tension and L_d the length when dry. In vertic horizons the COLE is more than 0.06.

Relationships with some other diagnostic horizons. Several other diagnostic horizons may also have high clay content, viz. the argic, natric and nitic horizons. These horizons lack the characteristic typical for the vertic horizon; however, they may be laterally linked in the landscape with the vertic horizon usually taking up the lowest position.

1. Slickensides are polished and grooved ped surfaces which are produced by one soil mass sliding past another.

Vitric horizon

General description. The vitric horizon (from L. vitrum, glass) is a surface or subsurface horizon dominated by volcanic glass and other primary minerals derived from volcanic ejecta.

Diagnostic criteria. A vitric horizon must have:

1. 10 percent or more volcanic glass and other primary minerals in the fine earth fraction; **and**
2. - a bulk density > 0.9 kg dm^3; **or**
   - Al_{ox} + ½Fe_{ox}[1] > 0.4 percent; **or**
   - phosphate retention >25 percent; **and**
3. thickness of at least 30 cm.

Field identification. The vitric horizon can be identified in the field with relative ease. It can occur as a surface horizon, however, it may also occur buried under some tens of centimetres of recent pyroclastic deposits. It has a fair amount of organic matter and a low clay content. The sand and silt fractions are still dominated by unaltered volcanic glass and other primary minerals (may be checked by x10 hand-lens).

Relationships with some other diagnostic horizons. Vitric horizons are closely linked with andic horizons, into which they may eventually develop. The amount of volcanic glass and other primary minerals, together with the amount of non-crystalline or paracrystalline pedogenetic minerals mainly separates the two horizons.

Vitric horizons may overlap with several diagnostic surface horizons, viz. the fulvic, melanic, mollic, umbric and ochric horizons.

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1. Al_{ox} and Fe_{ox} are acid oxalate (pH 3) extractable aluminium and iron, respectively (method of Blakemore *et al.*, 1987).

Yermic horizon

General description. The yermic horizon (from Sp. yermo, desert) is a surface horizon which usually, but not always, consists of surface accumulations of rock fragments ("desert pavement") embedded in a loamy vesicular crust and covered by a thin aeolian sand or loess layer.

Diagnostic criteria. A yermic horizon must have:

1. aridic properties; **and**
2. - a pavement which is varnished or includes wind-shaped gravel or stones ("ventifacts"); **or**
   - a pavement and a vesicular crust; **or**
   - a vesicular crust above a platy A horizon, without a pavement; **or**
   - a biological crust, 1-2 mm thick.

Field identification. A yermic horizon comprises a vesicular crust at the surface and underlying A-horizon(s). The crust, which has a loamy texture, shows a polygonal network of desiccation cracks, often filled with inblown material, which extend into the underlying horizons. Crust and the A-horizon(s) below have a weak to moderate platy structure.

Relationships with some other diagnostic horizons. Yermic horizons often occur in association with other diagnostic horizons characteristic for desert environments (salic, gypsic, duric, calcic and cambic horizons). In very cold deserts (e.g. Antarctica) they may occur associated with cryic horizons. Under these conditions coarse cryoclastic material dominates and there is little dust to be deflated and deposited by wind. Here a dense pavement with varnish, ventifacts, aeolian sand layers and soluble mineral accumulations may occur directly on loose C-horizons, without a vesicular crust and underlying A-horizons.