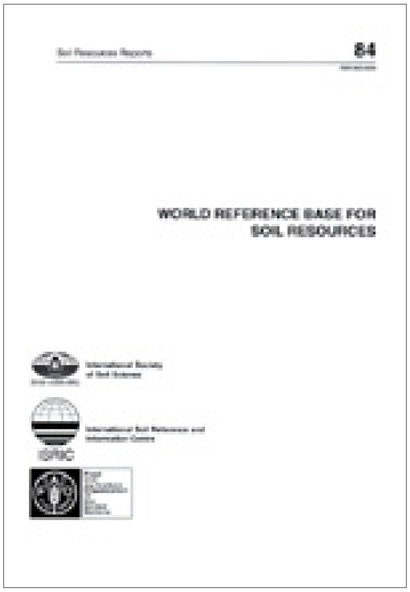

World reference base for soil resources

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1998

84 World Soil Resources Reports

International Society of Soil Science
ISSS-AISS-IBG

International Soil Reference and Information Centre
ISRIC

Food and Agriculture Organization of the United Nations

M-41
ISBN 92-5-104141-5

Contents

Foreword

After four years of intensive work since the 15th World Congress of Soil Science took place in Acapulco, Mexico, in 1994, three publications have been prepared on behalf of the Working Group Reference Base of the International Society of Soil Science, which highlight the present-day state of the art of tile 'World Reference Base for Soil Resources (WRB)'. The publications comprise:

1. World Reference Base for Soil Resources: Introduction.
2. World Reference Base for Soil Resources: Atlas.
3. World Reference Base for Soil Resources.

The first publication aims to serve as a first entry into the knowledge of soil diversity and soil distribution, accessible to disciplines other than 'soil science *sensu stricto*' and to a wider public. The second is an atlas providing an overview of the distribution of the reference soil groups in the world. The third one, presented here, can be seen as a technical manual, specifically for soil scientists. It gives the definitions and diagnostic criteria of the soil horizons, soil properties and soil materials, and contains a key for classifying the reference soil groups and their qualifiers.

The publications have been made possible by the sustained efforts of a large group of expert authors, and the cooperation and logistic support of ISSS, ISRIC and FAO.

It is hoped that these publications will contribute to the understanding of soil science in the public debate and in the scientific community.

J.A. Deckers (Chairman), O.C. Spaargaren (Vice Chairman) and F. O. Nachtergaele (Secretary)
ISSS Working Group Reference Base

L.R. Oldeman, Director
International Soil Reference and Information Centre
(ISRIC)

R Brinkman, Director
Land and Water Development Division
Food and Agriculture Organization of the United Nations
(FAO)

Acknowledgements

The text of this publication is based on the following contributions: *Acrisols* - Schargel (Venezuela); *Albeluvisols* - Langohr (Belgium) and Targulian (Russia); *Alisols* - Delvaux (Belgium), Herbillon and Volkov (France) and Constantini (Italy); *Andosols* - Quantin (France) and Shoji (Japan); *Anthrosols* - Gong Zi-tong (China) and Kosse (USA); *Arenosols*-Remmelzwaal (FAO) and Laker (South Africa); *Calcisols* - Ruellan (France); *Cambisols*-Laker (South Africa) and Spaargaren (The Netherlands); *Durisols* - Ellis (South Africa); *Ferralsols* - Eswaran (USA) and Klamt (Brazil); *Fluvisols* - Creutzberg (The Netherlands); *Gleysols* - Blume (Germany) and Zaidelman (Russia); *Gypsisols* - Ilaiwi (Syria) and Boyadgiev (Bulgaria); *Histosols* - Driessen (The Netherlands) and Okruszko (Poland); *Leptosols* - Bridges (UK); *Lixisols* - Schargel (Venezuela); *Luvisols* - Deckers and Dudal (Belgium); *Nitisols*-Sombroek (FAO) and Muchena (Kenya); *Planosols* - Brinkman (FAO); *Plinthosols* - Sombroek (FAO); *Podzols* - Righi (France); *Regosols* - Arnold (USA); *Solonchaks* - Loyer (France); *Solonetz* - Tursina (Russia); *Umbrisols* - Hollis (UK) and Nemecek (Czechia); *Vertisols*-Seghal (India).

Two thematic groups have worked out more detailed definitions, descriptions and subdivisions of the *Cryosols* on one hand, and the *Chernozems, Kastanozems* and *Phaeozems* on the other. *Cryosols* were dealt with by Tarnocai and Smith (Canada), Jakobsen (Denmark), Gilichinsky, Konyushkov, Naumov and Sokolov (Russia), Blume and Broll (Germany), and Bockheim, Kimble, Ping, Sletten and Swanson (USA), whereas the working group on *Chernozems, Kastanozems and Phaeozems* comprised Bronger (Germany), Gerasimova, Lebedeva, Makeev, Rozanov, Shoba and Sotnikov (Russia) and Pazos (Argentina).

Through secondment to FAO, F.R. Berding reviewed the contributions and existing literature on the *Andosols, Phaeozems* and *Podzols*. Many of his suggestions, particularly on the lower level separations of the reference soil groups, have been incorporated.

Many others have contributed through written comments, or through active participation in the discussions during the WRB or past International Reference Base (IRB) meetings. All these contributions are gratefully acknowledged as they have helped to build, refine and actualize the present *World Reference Base for Soil Resources.*

Special thanks go to J. Lozet and J. Chapelle (Belgium) who went through the meticulous task of translating the WRB publications into French. The efforts of E.M. Bridges (UK) to review the texts are also gratefully acknowledged.

Chapter 1: Background

It has been a matter of great concern that after a hundred years of modern soil science a generally accepted system of soil classification has not yet been universally adopted (Dudal, 1990). This situation arises partly from the fact that soils constitute a continuum which, unlike easily identifiable plants and animals, needs to be divided into classes by convention. To remedy this situation work in soil systematics during the past 20 years has concentrated upon the development of a *World Reference Base for Soil Resources*.

History

The *World Reference Base for Soil Resources* (WRB) is the successor to the International Reference Base for Soil Classification (IRB), an initiative of FAO, supported by the United Nations Environment Programme (UNEP) and the International Society of Soil Science, dating back to 1980. The intention of the IRB project was to work toward the establishment of a framework through which existing soil classification systems could be correlated and through which ongoing soil classification work could be harmonized. The final objective was to reach an international agreement on the major soil groupings to be recognized at a global scale as well as on the criteria and methodology to be applied for defining and identifying them. Such an agreement was meant to facilitate the exchange of information and experience, to provide a common scientific language, to strengthen the applications of soil science, and to enhance communication with other disciplines.

After preliminary discussions in 1978 in Canada, three meetings were convened in Sofia, Bulgaria, in 1981 and 1982, to initiate an international programme toward a common soil classification. Draft definitions of 16 major soil groups were formulated, *weakly developed soils, swelling/shrinking soils, groundwater influenced soils, saline/alkali soils, calcic/gypsic soils, mollic soils, umbric and shallow soils, sialic soils, fersialic soils, ferralic soils, andic soils, surface water influenced soils, podzolized soils, histic soils, pergelic soils and anthropogenic soils.*

The project to create an International Reference Base for Soil Classification was initiated in 1982 as one of the proposed programmes to implement a World Soils Policy through UNEP. It was envisaged that the International Reference Base for Soil Classification was to be used as a basis to revise the Legend of the Soil Map of the World (FAO-UNESCO, 1974).

In 1982, in New Delhi, India, the 12th Congress of the International Society of Soil Science (ISSS) endorsed this programme and entrusted it to a Working Group within Commission V (Soil Genesis, Classification and Cartography).

In 1986, at the 13th Congress of the ISSS in Hamburg, Germany, the IRB programme was placed in Commission V under the responsibility of its chairman, assisted by a core group. Selected contributors were asked to work out in greater detail the definitions of the major soil groupings and relevant diagnostic attributes, to make proposals for further subdivision at a second/third level, and to establish correlation with existing soil units of major soil classification systems.

The further development of the IRB was discussed at consultations held in Rome, Italy, in 1987 and in Almaty (Alma-Ata), Kazakstan, in 1988. Progress was reported in 1990 at a symposium devoted to the International Reference Base for Soil Classification during the 14th Congress of the International Society of Soil Science in Kyoto, Japan. At this stage 20 major soil groupings were identified on the basis of their representativeness of the world's soil cover, viz. *organic, anthric, vertic, andic, gleyic, stagnic, ferralic, podzic, luvic, nitic, lixic, fluvic, gypsic, calcic, salic, sodic, chernic, modic, cambic* and *primic* soils. The attributes used to define these soil groupings were selected to reflect major soil forming processes.

In the meantime FAO had issued the *Revised Legend of the Soil Map of the World* (FAO, 1988). The number of major soil groupings in this legend was increased from 26 to 28 and that of the soil units from 106 to 153. Some of the main changes included the amalgamation of *Lithosols*, *Rendzinas* and *Rankers* into *Leptosols*, the split of *Luvisols* into *Luvisols* and *Lixisols* and, similarly, the separation of *Acrisols* into *Acrisols* and *Alisols*, the deletion of *Xerosols* and *Yermosols*, and the introduction of *Anthrosols, Plinthosols, Calcisols* and *Gypsisols*. Some diagnostic criteria were adapted, others were newly defined (e.g. argic and ferralic B horizons, and andic, fluvic, gleyic, stagnic, nitic, salic and sodic properties).

As a follow-up to the 1990 Congress, a consultation was convened at Montpellier, France, in 1992, in order to take stock of the current status of the IRB in the light of the discussions held at the Kyoto Symposium. It had appeared that some of the 20 major soil groupings proposed were so broad that it proved difficult to prepare consistent definitions. These major soil groupings needed to be split in order to obtain a more significant subdivision. When comparing the Kyoto list of 20 IRB units and the 28 FAO major soil groupings of the Revised Legend, the question arose as to whether it was justified to develop two systems side by side. If a further split of some IRB units took place, one would end up with almost identical lists of units. Furthermore, as both IRB and the Soil Map of the World were co-sponsored by the ISSS, it was felt inappropriate to pursue two separate programmes which essentially had the same goal, namely to arrive at a rational inventory of global soil resources. An early motive for doing so had been that the 1974 FAO-UNESCO Legend was meant only to serve the sole purpose of the 1:5000000 Soil Map of the World. Since then, the Legend has progressively been developed to encompass the major soils of the world at three levels of generalization and is presently used widely for surveys both in developing and developed countries. Moreover, the terminology is well known and generally accepted.

Therefore it was decided that the IRB should adopt FAO's Revised Legend as a framework for its future activities. It would be IRB's task to apply its principles of definitions and soil relationships to the existing FAO units, providing greater depth and background. The merger of the two efforts was launched under the name: 'World Reference Base for Soil Resources', an ISSS/FAO/ISRIC undertaking.

When the Revised Legend was published in 1988, FAO called for continents and possible amendments. WRB has endeavoured to identify possible gaps and suggest adjustments accordingly. Proposed adjustments were presented in draft form during the 16th World Congress of Soil Science at Acapulco, Mexico (ISSS-ISRIC-FAO, 1994) and have been tested during meetings and field trips in Germany (1995), Russia (1996), South Africa (1996), Argentina (1997) and Austria (1997).

Objectives

The main objective of the *World Reference Base for Soil Resources* is **to provide scientific depth and background to the 1988 FAO Revised Legend**, incorporating the latest knowledge relating to global soil resources and their interrelationships. To include some of the most recent pedological studies and to expand use of the system from an agricultural base to a broader environmental one. it was recognized that a limited number of important changes to the 1988 Legend were becoming necessary.

More specifically, the objectives are:

- to develop an internationally acceptable system for delineating soil resources to which national classifications can be attached and related, using FAO's Revised Legend as a framework;
- to provide this framework with a sound scientific basis so that it can also serve different applications in related fields such as agriculture, geology, hydrology and ecology;
- to recognize within the framework important spatial relationships of soils and soil horizons as characterized by topo- and chronosequences; and
- to emphasize the morphological characterization of soils rather than to follow a purely laboratory-based analytical approach.

WRB is designed as **an easy means of communication amongst scientists** to identify, characterize and name major types of soils. It is not meant to replace national soil classification systems, but be a tool for better **correlation between national systems**. It aims to act as a common denominator through which national systems can be compared. WRB also serves as a common ground among people with an interest in land and natural resources.

WRB is also a tool for **identifying pedological structures** and their significance. It serves as a **basic language in soil science** to facilitate:

- scientific communication;
- implementation of soil inventories and transfer of pedological data, elaboration of different systems of classification having a common base, interpretation of maps;
- acknowledgement of relationships between soils and soil horizon distribution as characterized by topo- and chronosequences;
- international use of pedological data, not only by soil scientists but also by other users of soil and land, such as geologists, botanists, agronomists, hydrologists, ecologists, farmers, foresters, civil engineers and architects, with as a particular objective to improve upon:
    - the use of soil data for the benefit of other sciences;
    - the evaluation of soil resources and the potential use of different types of soil

cover;

- the monitoring of soils, particularly soil development which is dependent on the way soils are used by the human community;

- the validation of experimental methods of soil use for sustainable development, which maintain and, if possible, improve the soil's potential;

- transfer of soil use technologies from one region to another.

Principles

The general principles on which the WRB is based were laid down during the early Sofia meetings in 1981 and 1982, and further elaborated upon by the Working Groups entrusted with its development. These general principles can be summarized as follows:

• the classification of soils is based on soil properties defined in terms of diagnostic horizons and characteristics, which to the greatest extent possible should be measurable and observable in the field;

• the selection of diagnostic horizons and characteristics takes into account their relationship with soil forming processes. It is recognized that an understanding of soil forming processes contributes to a better characterization of soils but that they should not, as such, be used as differentiating criteria;

• to the extent possible at a high level of generalization it is attempted to select diagnostic features which are of significance for management purposes;

• climatic parameters are not applied in the classification of soils. It is fully realized that they should be used for interpretation purposes, in dynamic combination with soil properties, but they should not be part of soil definitions;

• WRB is meant to be a comprehensive classification system which enables people to accommodate their own national classification system. It comprises two tiers of categorical detail:

1. the "Reference base" which is limited to the first level only, having 30 reference soil groups; and

2. the "WRB Classification System" consisting of combinations of a set of prefixes as unique qualifiers (or modifiers) added to the reference soil groups, allowing very precise characterization and classification of individual soil profiles;

• the reference soil units in WRB should be representative of major soil regions so as to provide a comprehensive overview of the world's soil cover;

• the reference base is not meant to substitute for national soil classification systems but rather to serve as a common denominator for communication at an international level. This implies that lower-level categories, possibly a third category of the WRB, could accommodate local diversity at country level. Concurrently the lower levels could emphasize soil features which are important for land use and soil management;

- the Revised Legend of FAO/UNESCO Soil Map of the World has been used as a basis for the development of the WRB in order to take advantage of the international soil correlation work which has already been conducted through this project;

- definitions and descriptions of soil units are to reflect variations in soil characteristics both vertically and laterally so as to account for spatial linkages within the landscape;

- the term 'Reference Base' is connotative of the common denominator function which the WRB will assume. Its units should have sufficient width to stimulate harmonization and correlation of existing national systems;

- in addition to serving as a link between existing classification systems the WRB may also serve as a consistent communication tool for compiling global soil databases and for the inventory and monitoring of the world's soil resources.

- the nomenclature used to distinguish soil groups will retain terms which have been traditionally used or which can easily be introduced in current language. These terms are precisely defined in order to avoid the confusion which occurs when names are used with different connotations.

Although the basic framework of the FAO Legend, with its two categoric levels and guidelines for developing classes at a third level, was adopted, it has been decided to merge the lower levels. Each reference soil group of WRB is provided with a listing of possible qualifiers in a priority sequence, from which the user can construct the various lower-level units. The broad principles which govern the WRB class differentiation are:

- at the **higher categoric level** classes are differentiated mainly according to the primary pedogenetic process that has produced the characteristic soil features, except where 'special' soil parent materials are of overriding importance; and

- at the **lower categoric levels** classes are differentiated according to any predominant secondary soil forming process that has significantly affected the primary soil features. In certain cases, soil characteristics that have a significant effect on use may be taken into account.

It is recognized that a number of reference soil groups may occur under different climatic conditions. It was decided, however, not to introduce separations on account of climatic characteristics so that the classification of soils is not subordinated to the availability of climatic data.

Elements of the world reference base for soil resources

The WRB reference soil groups

After reviewing FAO's Revised Legend, 30 reference soil groups were identified to constitute the World Reference Base for Soil Resources. Three new reference soil groups are included: the *Cryosols*, *Durisols*, and *Umbrisols*. The *Greyzems* have been merged with the *Phaeozems*, and the *Podzoluvisols* are renamed *Albeluvisols*.

The 30 major soil groups of the WRB are *Acrisols, Albeluvisols, Alisols, Andosols, Anthrosols, Arenosols, Calcisols, Cambisols, Chernozems, Cryosols, Durisols, Ferralsols, Fluvisols, Gleysols, Gypsisols, Histosols, Kastanozems, Leptosols, Lixisols, Luvisols, Nitisols, Phaeozems, Planosols, Plinthosols, Podzols, Regosols, Solonchaks, Solonetz, Umbrisols*, and *Vertisols*.

Cryosols are introduced at the highest level to identify a group of soils which occur under the unique environmental conditions of alternating thawing and freezing. These soils have permafrost within 100 cm of the soil surface and are saturated with water during the period of thaw. In addition, they show evidence of cryoturbation. ***Durisols*** comprise the soils in semi-arid environments which have an accumulation of secondary silica, either in the form of nodules, or as a massive, indurated layer. ***Umbrisols*** cover the soils which have either an umbric horizon, or have a mollic horizon and a base saturation of less than 50 percent in some parts within the upper 125 cm of the soil surface. They are a logical counterpart of the *Chernozems, Kastanozems* and *Phaeozems*.

The ***Plinthosols*** bring together the *Plinthosols* of the Revised Legend and the soils which have a petroplinthic layer at shallow depth. In the Revised Legend the latter soils belong to the *Leptosols*. For the World Reference Base it was decided to exclude from the *Leptosols* soils with pedogenetic horizons such as indurated calcic or gypsic horizons or hardened plinthite. This necessitated the definition of a reference soil group which included these soils. Although it is realized that soils with shallow petroplinthic layers and soils having plinthite normally occupy different positions in the landscape, it was felt appropriate to group them together as they are genetically related.

Podzoluvisols are renamed ***Albeluvisols***. The name *Podzoluvisols* suggests that in these soils both the processes of cheluviation (leading to *Podzols*) and subsurface accumulation of clay (resulting in *Luvisols*) take place, while in fact the dominant process consists of removal of clay and iron/manganese along preferential zones (pea faces, cracks) in the argic horizon. The name *Albeluvisols* is therefore thought to be more appropriate, expressing the presence of a bleached eluvial horizon ("*albic horizon*"), a clay-enriched horizon ("*argic horizon*") and the occurrence of "*albeluvic tonguing*".

WRB diagnostic horizons, properties and materials

Earlier it was agreed that the soil groups should be defined in terms of a specific combination of soil horizons, called '***reference horizons***' rather than '***diagnostic horizons***'. Reference horizons were intended to reflect genetic horizons which are widely recognized as occurring in soils. Unfortunately, the distinction between reference and diagnostic horizons created confusion and it was agreed to retain the FAO terminology of diagnostic horizons as well as the diagnostic properties. Additionally it appeared necessary to define diagnostic soil materials. This together resulted in a comprehensive list of WRB diagnostic horizons, properties and materials, defined in terms of morphological characteristics and/or analytical criteria. In line with the WRB objectives, attributes are described as much as possible to help field identification.

Modifications to definitions of FAO's diagnostic horizons and properties

Of the 16 diagnostic horizons of the Revised Legend only *the fimic A horizon* has not been retained. It covers too wide a range of human-made surface layers and is replaced in the WRB by the hortic, plaggic and ferric horizons.

For the WRB, the definition of the ***histic horizon*** was broadened by reducing its minimum thickness to 10 cm and removing the maximum thickness. This is because of a second use of the definition. In the

Revised Legend the histic H horizon is used to distinguish soils at second level to identify histic soil units; in the WRB it is used also at the highest level to define *Histosols*. It was agreed that *Histosols* over continuous hard rock should have a minimum thickness of 10 cm in order to avoid very thin organic layers over rock being classified as *Histosols*.

The P_2O_5 content requirement for FAO's mollic and umbric A horizons has been deleted from the WRB definition of ***mollic*** and ***umbric horizons***. This requirement cannot be considered diagnostic since thick, dark coloured, human-made horizons in, for instance, China, also have low amounts of phosphate. Other criteria have to be found to separate mollic and umbric horizons from anthropedogenic horizons.

A ***chernic horizon*** is defined as a special kind of mollic horizon. The present definition of the mollic horizon was felt to be too broad to reflect properly the unique characteristics of the deep, blackish, porous surface horizons which are so typical for *Chernozems*.

The definition of the ***ochric horizon*** is similar to the ochric A horizon. The colour requirement for the ***albic horizon*** have been slightly changed compared to FAO's albic E horizon, to suit albic horizons which show a considerable shift in chrome upon moistening. Such conditions are frequently found in soils of the southern hemisphere.

The ***argic horizon*** definition differs from that of the argic B horizon of the Revised Legend in that the percentage clay skins on both horizontal and vertical ped faces and in pores has been increased from one to five percent. This is expected to provide a better correlation with the earlier requirement of at least one percent oriented clay in thin sections.

Guidelines to recognize a lithological discontinuity, if not clear from the field observation, were added to the description of the argic horizon. It 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 United States Department of Agriculture (USDA) system or other), or by changes in the content of gravel and coarser fractions. A relative change of at least 20 percent in any of the major particle size fractions is regarded as diagnostic for a lithological discontinuity. However, it should only be taken into account if it is located in the section of the solum where the clay increase occurs and if there is evidence that the overlying layer was coarser textured.

The adjustments made in the description of the argic horizon also apply to the ***natric horizon***.

The definition of FAO's cambic B horizon has been slightly amended by deleting the requirement '....*and has at least eight percent clay*'. This requirement forces some soils, which have a well-developed structural-B horizon and silt loam or silt textures with a low clay content, as found, for instance, in fluvio-glacial deposits of the nordic countries, into the *Regosols* rather than in the *Cambisols*. Because there is also no need for this requirement to separate *Cambisols* from *Arenosols* (defined in the WRB as soils having a loamy sand or coarser texture) it has not been used in the definition proposed for the WRB ***cambic horizon***.

Major alterations are made in the definition of the ***spodic horizon***. It has been brought into line with the recent modifications in soil taxonomy (Soil Survey Staff, 1996) regarding the definition of spodic materials. Colour requirements were added, a limit of 0.5 or more in percentage oxalate extractable aluminium plus half that of iron is used, and a value for the optical density of oxalate extract (ODOE) of 0.25 or more is introduced. Moreover, the upper limit of spodic horizons has been set at 10 cm depth.

The silt-clay ratio of 0.2 or less has been deleted from the definition of the ***ferralic horizon***. This criterion was felt to be too strict; the silt particle size fraction has been increased from 2-50 to 2-63 µm (FAO, 1990). Other values have been proposed (silt-clay ratio of 0.7 or less; fine silt-clay ratio of 0.2 or less) but, as yet, no consensus has been reached.

Some alterations are made in the definitions of the ***calcic*** and ***gypsic horizons***. For WRB purposes they are split into calcic/gypsic and ***hypercalcic/hypergypsic horizons***. These latter horizons have a calcium carbonate equivalent and gypsum content of 50 and 60 percent, respectively, but are not cemented.

The definition for the ***sulfuric horizon*** remains the same as in the Revised Legend.

In addition to these diagnostic horizons, 19 new ones are proposed. Some are adopted from FAO's diagnostic properties, others are newly formulated. Together they bring the total of diagnostic horizons recognized in the WRB to 34. The newly defined diagnostic horizons are the *andic, anthropedogenic, chernic, cryic, duric, ferric, folic, fragic, fulvic, glacic, melanic, nitic, petroduric, petroplinthic, plinthic, salic, takyric, vertic, vitric* and *yermic horizons*. Definitions and descriptions are given in *Chapter 3*.

A combination of an *anthraquic horizon* at the surface with an underlying *hydragric horizon*, totalling together a thickness of at least 50 cm, defines certain *Anthrosols* which show evidence of alteration through wet-cultivation practices. It comprises a puddled layer, a plough pan and an illuvial subsurface horizon. This combination is characteristic for soils which have been used for long-term paddy rice cultivation.

Newly defined diagnostic properties and materials are *albeluvic tonguing, alic* and *aridic properties*, and *anthropogeomorphic, calcaric, fluvic, gypsiric, organic, sulfidic* and *tephric soil material*. Descriptions and definitions are also given in *Chapter 3*.

Gleyic and *stagnic properties* have been reformulated. Slight changes are made in FAO's definitions of *abrupt textural change and geric properites*, while the definitions of *permafrost* and soft powdery lime, renamed *secondary carbonates*, have been adopted without change.

In the description of the ***gleyic*** and ***stagnic properties*** the occurrence of 'gleyic' and 'stagnic colour patterns' is introduced. These terms apply to the specific distribution pattern of Fe/Mn (hydr)oxides caused by saturation with groundwater or stagnating surface water. A gleyic colour pattern has 'oximorphic' features on the outside of structural elements, along root channels and pores, or as a gradient upwards in the soil. A stagnic colour pattern on the other hand shows these features in the centre of peas or as a gradient downwards resulting from impedance of the water flow.

The slight changes in the descriptions of ***abrupt textural change*** and ***geric properties*** refer to a different depth in which tile change in texture must occur and another way of calculating the effective cation exchange capacity (ECEC)[1], respectively.

[1] ECEC: effective cation exchange capacity (sum of exchangeable bases **plus** extractable acidity).

Discussion

Soil cover: vertical and lateral morphology and its functioning

Soil cover

The soil cover is a continuous natural body which has three spatial and one temporal dimension. The three main features governing the soil cover are:

- It is formed by **mineral and organic constituents** and includes solid, liquid and gaseous phases.

- The constituents are organized in **structures**, specific for the pedological medium. These structures form the morphological aspect of the soil cover, equivalent to the anatomy of a living being. They result from the history of the soil cover and from its actual dynamics and properties. Study of the soil cover structures facilitates perception of the physical, chemical and biological properties, it permits understanding of the past and present of the soil, and predicting its future.

- The soil cover is in **constant evolution**, thus giving the soil its fourth dimension, time.

Structure of the soil

The morphological organization of the soil cover exists at different scales of observation: from the basic assemblages of particles which can be observed through a microscope, to the arrangement of pedological systems at the scale of a landscape. Four types of structures, corresponding with four levels of organization and observation of the soil cover, are particularly important to be described, measured and understood:

1. **Elementary organizations**: structures made up of the constituents. They are visible with the naked eye, or through a microscope. The main types of elementary organizations are aggregates (peds), voids (porosity), cutans, nodules, features of biological activity; colour of the soil material helps to recognize and understand the elementary organization.

2. **Assemblages**: pedological volumes determined by the presence of various elementary organizations. Examples of assemblages are andic, calcic, ferralic, vertic, etc.; each of these assemblages can be recognized in terms of specific associations of colour, peas, voids, cutans, nodules, etc.

3. **Horizons**: pedological volumes more or less parallel to the surface of the earth. A horizon is described by the presence of one or more types of assemblages and by the relationship between these assemblages. It is also described by its thickness, by its lateral extension, and by its vertical and lateral morphological limits. At the scale of a landscape, horizons are never infinite; laterally they disappear or merge into another horizon.

4. **Pedological systems**: spatial distributions and relationships of horizons at the scale of the landscape (Ruellan and Dosso, 1993). The structure of a pedological system can be

described by the arrangement of the horizons: elementary organizations and assemblages of the horizons, vertical superposition and lateral successions of horizons, kinds of limits which separate the horizons.

The pedological studies have, until now, mainly considered the characterization and the genetic significance of the elementary organizations, of the assemblages, of the horizon itself and of the vertical sequences of horizons. Relatively few detailed studies have been made with regard to the three-dimensional, spatial organization of the soil cover and with respect to the historical and actual dynamics of the three-dimensional organization. Such studies are needed to understand the dynamic soil entities or soil units, at the scale of the landscape and ecosystems, and to disclose the relationships between the pedosphere and the other components of the earth: lithosphere, hydrosphere, atmosphere, biospere.

A morphogenetic soil reference system such as WRB is based on elementary organizations, assemblages, horizons, and the vertical superpositions of horizons. However, a comprehensive reference system for lateral distributions cannot yet be constructed with enough precision. Recognizing the existence of these lateral distributions, they are acknowledged, wherever possible, in the definition of the components of the WRB, thus opening the possibility to start a World Reference Base concerning pedological systems (lithosequences, toposequences, chronosequences, biosequences, climasequences, etc.)

Problems encountered

A basic philosophy in the WRB is that the final soil groups must show coherence in geographical distribution and pedogenetic character, and that soils preferably must be characterized by their morphological expression rather than by analytical data. In a number of proposed major soil groups this has led to divisions and in others to amalgamation. For example, FAO's Leptosols comprise "*soils limited in depth by.... a continuous cemented layer within 30 cm of the surface*", i.e. petrocalcic, petrogypsic, petroferric layers or duripan. These layers are considered in the WRB as pedogenetic horizons and soils having such layers should therefore be classed with their appropriate groups. Consequently, shallow soils over petrocalcic, petroduric, petrogypsic or petroplinthic horizons are grouped in the World Reference Base with the *Calcisols*, *Durisols*, *Gypsisols* and *Plinthosols*, respectively. It must be emphasized, however, that shallow soils over a petroplinthic horizon may occupy distinctly different positions in the landscape than those containing a plinthic horizon. The latter usually occur in depressions and on extensive plains, while the former are frequently encountered in elevated positions, e.g. as 'cuirasses' in western Africa, forming caps of table lands.

Leptosols also comprise soils with a very high content in coarse fragments. This combination left the *Leptosols* an odd group of either shallow soils or relatively deep soils, with as a common characteristic a low amount of available moisture. There was a proposal to group the deeper *Leptosols* with the *Regosols*. This would have purified the *Leptosols* but 'polluted' the *Regosols*. Therefore, coarse fragmental soils are retained in the *Leptosols*.

A major concern has become how to treat human-influenced soils which do not qualify as *Anthrosols*. Especially in the reference soil groups of *Podzols*, *Umbrisols* and *Arenosols*, soils occur in which the surface layer has been modified by fertilization and liming to such an extent that the original characteristic of low base saturation has disappeared. If left to nature, the initial low base saturation will return in time. Following the principle that short-term management effects should not influence soil grouping, these kind of soils are kept with the *Podzols, Umbrisols* and *Arenosols,* and an "*anthric*" modifier may be used to indicate human influence.

Interfaces between some soils in the Revised Legend are arbitrary. FAO's separation of *Luvisols, Alisols, Acrisols* and *Lixisols* may be very useful, but their identification is based largely on analytical data, whereas differences between the soils are difficult to detect in the field. At one stage it was proposed to group *Luvisols* together with *Alisols* and *Acrisols* together with *Lixisols*. The result would have been that two very different soils in Africa would have been classed together, and that the fertile *Luvisols* of the loess belt in western Europe would have been grouped together with the extremely acid and infertile *Alisols* of the foothills in the Andes or on Kalimantan, thus ignoring the WRB principle of relationships in soil geographical distribution. It was therefore decided to retain the separation made in the Revised Legend, to base the difference between *Luvisols* and *Alisols* mainly on "*alic properties*", and to continue the search for morphological and associated criteria which would enable the four 'luvic' soils to be distinguished better in the field. Such criteria could be based, for instance, on their structural development.

Similar problems exist between *Andosols* and *Podzols*, especially between the *Andosols* which are dominated by alumino-organic complexes, and *Podzols* lacking an albic horizon. No sound field differentiating criteria could be established, apart from circumstantial evidence derived from the geography of the area, and so a clear distinction between the two soils still needs the support of analytical tests.

The limit between *Ferralsols* and *Nitisols* in the Revised Legend is unsatisfactory. Many *Nitisol*-like soils have nitic properties and also a ferralic B horizon; consequently they key out as *Ferralsols*. The general concept of *Ferralsols*, however, is that of soils which have weakly developed structures and are low in active Si, Al and Fe. In contrast, nitic properties apply to soil materials which are strongly structured and have a high content of active iron (FAO, 1988). This apparent contradiction has been removed in WRB by excluding the presence of a nitic horizon in *Ferralsols* and, at the same time, providing the possibility of an intergrade in *Nitisols* to *Ferralsols* by the qualifier "Ferralic".

Consensus has been reached on the problem concerning priority between ferralic horizons and argic horizons containing low activity clays. Horizons with a CEC of 16 $cmol_c$ kg^{-1} clay or less qualify for ferralic, provided all other requirements are met. If, however, the ferralic horizon is overlain by a horizon which qualifies for an argic horizon and which contains in its upper 30 cm more than 10 percent water-dispersible clay, the argic horizon takes precedence over the underlying ferralic horizon for classification purposes.

Standard depths of 10, 20, 25, 30, 40, 50, 75, 100, 150 and 200 cm have been used, unless there is an overriding argument not to do so. Such an argument can be the use of another depth value in the national classification system from which a description has been taken. This ensures compliance with one of the main WRB objectives, namely to serve as an internationally acceptable framework for delineating soil resources, to which national classifications can be attached and related.

Correlation with existing classification systems

The WRB, having taken the framework of the Revised Legend as a guide, obviously bears many similarities to it. The nomenclature has been adopted and, where necessary, adapted using the set rules. Its concepts of diagnostic horizons and properties, supplemented with diagnostic soil materials, have been incorporated.

The original FAO Legend (FAO-UNESCO, 1974) was built on knowledge and experience of many soil scientists from all over the world and reflects a consensus derived from a number of classification systems. For example, the *Greyzems*, *Chernozems* and *Kastanozems* stem from tile older Russian classification of Grey Forest soils, *Chernozems* and Chestnut soils. Similarly, *Cambisols* coincide largely with the German 'Braunerde' and the French 'Sols bruns', while *Ferralsols* closely follow the concept of the American Oxisols and Brazilian Latosols.

The *World Reference Base for Soil Resources* continues to build on existing classification systems. The *Anthrosols* contain many elements from the *Chinese Soil Taxonomic Classification System* (CSTC Research Group, 1995), the description and definition of *Andosols* correlates closely with the Andisols of the *Référentiel pédologique* (AFES, 1995), as is the case, to a lesser extent, with the Podzols and the French *Podzosols*. On the other hand, some of the proposals for *Solonchaks, Gleysols*, *Plinthosols*, *Ferralsols*, *Durisols*, *Alisols*, *Umbrisols* and *Regosols* result from original ideas not yet reflected in current classification systems.

Chapter 2: Key to the reference soil groups

For describing and defining the reference soil groups of the *World Reference Base for Soil Resources*, use is made of soil characteristics, properties and horizons which are combined to define soils and their relationships.

Soil characteristics are single parameters which are observable or measurable in the field or laboratory, or can be analysed using microscope techniques. They include such characteristics as colour, texture and structure of the soil, features of biological activity, arrangement of voids and pedogenic concentrations (mottles, cutans nodules, etc.) as well as analytical determinations (soil reaction, particle-size distribution, cation exchange capacity, exchangeable cations, amount and nature of soluble salts, etc.).

Soil properties are combinations ("assemblages") of soil characteristics which are known to occur in soils and which are considered to be indicative of present or past soil-forming processes (e.g. vertic properties, which are a combination of heavy texture, smectitic mineralogy, slickensides, hard consistence when dry, sticky when wet, shrinking when dry and swelling when wet).

Soil horizons are three-dimensional pedological bodies which are more or less parallel to the earth's surface. Each horizon contains one or more property, occurring over a certain depth, which characterizes it. The thickness varies from a few centimetres to several metres; most commonly it is about a few decimetres. The upper and lower limits ("boundaries") are gradual, clear or abrupt. Laterally, the extension of a soil horizon varies greatly, from a metre to several kilometres. However, a soil horizon is never infinite. Laterally, it disappears or grades into another horizon.

Soils are defined by the vertical combination of horizons, occurring within a defined depth, and by the lateral organization ("sequence") of the soil horizons, or by the lack of them, at a scale reflecting the relief or a land unit.

Key to the reference soil groups of the world reference base for soil resources

Soils having a *histic* or *folic* horizon,

1. ***either*** a. 10 cm or more thick from the soil surface to a lithic or paralithic contact;
or b. 40 cm or more thick and starting within 30 cm from the soil surface; ***and***

2. lacking an *andic* or *vitric* horizon starting within 30 cm from the soil surface.

HISTOSOLS (HS)

Other soils having one or more *cryic* horizons within 100 cm from the soil surface.

CRYOSOLS (CR)

Other soils having ***either***

1. a *hortic, irragric, plaggic* or *terric* horizon 50 cm or more thick; ***or***

2. an *anthraquic* horizon and an underlying *hydragric* horizon with a combined thickness of 50 cm or more.

ANTHROSOLS (AT)

Other soils, which are ***either***

1. Imitated in depth by *continuous hard rock* within 25 cm from the soil surface; ***or***

2. overlying material with a calcium carbonate equivalent of more than 40 percent within 25 cm from the soil surface; ***or***

3. containing less than 10 percent (by weight) fine earth to a depth of 75 cm or more from the soil surface; ***and***

4. having no diagnostic horizons other than a *mollic, ochric, umbric, yermic or vertic* horizon.

LEPTOSOLS (LP)

Other soils having

1. a *vertic* horizon within 100 cm from the soil surface; ***and***

2. after the upper 20 cm have been mixed, 30 percent or more clay in all horizons to a depth of 100 cm or more, or to a contrasting layer (lithic or paralithic contact, *petrocalcic*, *petroduric* or *petrogypsic* horizons, sedimentary discontinuity, etc.) between 50 and 100 cm; ***and***

3. cracks[2] which open and close periodically.

[2] A crack is a separation between gross polyhedrons. If the surface is strongly self-mulching, i.e. a mass of granules ("*grumic*"), or if the soil is cultivated while cracks are open, the cracks may be filled mainly by granular materials from the soil surface but they are open in the sense that the polyhedrons are separated. A crack is regarded as open if it controls the infiltration and percolation of water in dry, clayey soil (Soil Survey Staff, 1996). If the soil is irrigated the upper 50 cm has a coefficient of linear extensibility (COLE) of 0.06 or more throughout.

VERTISOLS (VR)

Other soils having

1. *fluvic* soil material starting within 25 cm from the soil surface and continuing to a depth of at least 50 cm from the soil surface; ***and***

2. no diagnostic horizons other than a *histic, mollic, ochric, takyric, umbric, yermic, salic* or

sulfuric horizon.

FLUVISOLS (FL)

Other soils having

1. a *salic* horizon starting within 50 cm from the soil surface; ***and***

2. no diagnostic horizons other than a *histic, mollic, ochric, takyric, yermic, calcic, cambic, duric, gypsic* or *vertic* horizon.

SOLONCHAKS (SC)

Other soils having

1. *gleyic* properties within 50 cm from the soil surface; ***and***

2. no diagnostic horizons other than a anthraquic, *histic, mollic, ochric, takyric, umbric, andic, calcic, cambic, gypsic, plinthic, salic, sulfuric* or *vitric* horizon within 100 cm from the soil surface.

GLEYSOLS (GL)

Other soils having

1. ***either*** a *vitric* ***or*** an *andic* horizon starting within 25 cm from the soil surface; ***and***

2. having no diagnostic horizons (unless buried deeper than 50 cm) other than a *histic, fulvic, melanic, mollic, umbric, ochric, duric* or *cambic* horizon.

ANDOSOLS (AN)

Other soils having a *spodic* horizon starting within 200 cm from the soil surface, underlying an *albic, histic, umbric* or *ochric* horizon, or an *anthropedogenic* horizon less than 50 cm thick.

PODZOLS (PZ)

Other soils having ***either***

1. a *petroplinthic* horizon starting within 50 cm from the soil surface; ***or***
2. a *plinthic* horizon starting within 50 cm from the soil surface; ***or***
3. a *plinthic* horizon starting within 100 cm from the soil surface when underlying either an *albic* horizon or a horizon with *stagnic* properties.

PLINTHOSOLS (PT)

Other soils

1. having a *ferralic* horizon at some depth between 25 and 200 cm from the soil surface; ***and***

2. lacking a *nitic* horizon within 100 cm from the soil surface; ***and***

3. lacking a layer which fulfils the requirements of an *argic* horizon and which has in the upper 30 cm, 10 percent or more water-dispersible clay (unless the soil material has *geric*

properties or more than 1.4 percent organic carbon).

FERRALSOLS (FR)

Other soils having a *natric* horizon within 100 cm from the soil surface.

SOLONETZ (SN)

Other soils having

1. an eluvial horizon, the lower boundary of which is marked, within 100 cm from the soil surface, by an *abrupt textural change* associated with *stagnic* properties above that boundary; ***and***

2. no *albeluvic tonguing*.

PLANOSOLS (PL)

Other soils having

1. a *mollic* horizon with a moist chrome of 2 or less if the texture is finer than sandy loam, or less than 3.5 if the texture is sandy loam or coarser, both to a depth of at least 20 cm, or having these chromes directly below any plough layer; ***and***

2. concentrations of *secondary carbonates* starting within 50 cm of the lower limit of the Ah horizon but within 200 cm from the soil surface; ***and***

3. no *petrocalcic* horizon between 25 and 100 cm from the soil surface; ***and***

4. no secondary gypsum; ***and***

5. no uncoated silt and sand grains on structural ped surfaces.

CHERNOZEMS (CH)

Other soils having

1. a *mollic* horizon with a moist chrome of more than 2 to a depth of at least 20 cm, or having this chrome directly below any plough layer; ***and***

2. concentrations of *secondary carbonates* within 100 cm from the soil surface; ***and***

3. no diagnostic horizons other than an *argic, calcic, cambic, gypsic* or *vertic* horizon.

KASTANOZEMS (KS)

Other soils having

1. a *mollic* horizon; ***and***

2. a base saturation (by 1 *M* NH_4OAc) of 50 percent or more and a calcium carbonate-free soil matrix at least to a depth of 100 cm from the soil surface, or to a contrasting layer (lithic or paralithic contact, *petrocalcic* horizon) between 25 and 100 cm; ***and***

3. no diagnostic horizons other than an *albic, argic, cambic* or *vertic* horizon, or a *petrocalcic* horizon[3] in the substratum.

[3] A *petrocalcic* horizon may be present locally (e.g. tile "Tosca" in Argentina). Such petrocalcic *horizons are considered to be polygenetic and may best be handled for classification purposes at phase level (e.g. Luvic Phaeozem, Tosca phase).*

PHAEOZEMS (PH)

Other soils having

1. ***either*** a *gypsic* or *petrogypsic* horizon within 100 cm from the soil surface, ***or*** 15 percent (by volume) or more gypsum, which has accumulated under hydromorphic conditions, averaged over a depth of 100 cm; ***and***

2. no diagnostic horizons other than an *ochric* or *cambic* horizon, an *argic* horizon permeated with gypsum or calcium carbonate, a *vertic* horizon, or a *calcic* or *petrocalcic* horizon underlying the gypsic horizon.

GYPSISOLS (GY)

Other soils having a *duric* or *petroduric* horizon within 100 cm from the soil surface.

DURISOLS (DU)

Other soils having

1. a *calcic* or *petrocalcic* horizon within 100 cm of the surface; ***and***

2. no diagnostic horizons other than an *ochric* or *cambic* horizon, an *argic* horizon which is calcareous, a *vertic* horizon, or a *gypsic* horizon underlying a petrocalcic horizon.

CALCISOLS (CL)

Other soils having an *argic* horizon within 100 cm from the soil surface with an irregular upper boundary resulting from *albeluvic tonguing* into the argic horizon.

ALBELUVISOLS (AB)

Other soils having

1. an *argic* horizon, which has a cation exchange capacity (by 1 *M* NH_4OAc) of 24 $cmol_c$ kg^{-1} clay or more, either starting within 100 cm from the soil surface, or within 200 cm from the soil surface if the argic horizon is overlain by loamy sand or coarser textures throughout; ***and***

2. *alic* properties in the major part between 25 and 100 cm from the soil surface; ***and***

3. no diagnostic horizons other than an ochric, *umbric, albic, andic, ferric, nitic, plinthic* or *vertic* horizon.

ALISOLS (AL)

Other soils having

1. a *nitic* horizon starting within 100 cm from the soil surface; ***and***

2. gradual to diffuse horizon boundaries between the surface and the underlying horizons; ***and***

3. no *ferric*, *plinthic* or *vertic* horizon within 100 cm from the soil surface.

NITISOLS (NT)

Other soils having

1. an *argic* horizon, which has a cation exchange capacity (by 1 *M* NH_4OAc) of less than 24 $cmol_c$ kg^{-1} clay in some part, either starting within 100 cm from the soil surface, or within 200 cm from the soil surface if the argic horizon is overlain by loamy sand or coarser textures throughout, ***and***

2. a base saturation (by 1M NH_4OAc) of less than 50 percent in the major part between 25 and 100 cm.

ACRISOLS (AC)

Other soils having an argic horizon with a cation exchange capacity (by 1 M NH_4OAc) equal to or more than 24 $cmol_c$ kg^{-1} clay throughout.

LUVISOLS (LV)

Other soils having an *argic* horizon.

LIXISOLS (LX)

Other soils having

1. an *umbric* horizon; ***and***

2. no diagnostic horizons other than an *anthropedogenic* horizon less than 50 cm thick, or an *albic* or *cambic* horizon.

UMBRISOLS (UM)

Other soils having ***either***

1. a *cambic* horizon; ***or***

2. a *mollic* horizon overlying a subsoil which has a base saturation (by 1 *M* NH_4OAc) of less than 50 percent in some part within 100 cm from the soil surface; ***or***

3. one of the following diagnostic horizons within the specified depth from the soil surface:

   a. an *andic*, *vertic* or *vitric* horizon starting between 25 and 100 cm;

b. a *plinthic*, *petroplinthic* or *salic* horizon starting between 50 and 100 cm, in the absence of loamy sand or coarser textures above these horizons.

CAMBISOLS (CM)

Other soils having

1. a texture which is loamy sand or coarser ***either*** to a depth of at least 100 cm from the soil surface, ***or*** to a *plinthic*, *petroplinthic* or *salic* horizon between 50 and 100 cm from the soil surface; ***and***

2. less than 35 percent (by volume) of rock fragments or other coarse fragments within 100 cm from the soil surface; ***and***

3. no diagnostic horizons other than an *ochric*, *yermic* or *albic* horizon, or a *plinthic, petroplinthic* or *salic* horizon below 50 cm from the soil surface, or an *argic* or *spodic* horizon below 200 cm depth.

ARENOSOLS (AR)

Other soils.

REGOSOLS (RG)

Chapter 3: 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[4] for individual profiles (Bennema and Camargo, 1979; Brinkman, 1979; Klamt and Sombroek, 1988).

> [4] 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 tile contribution of the organic C to tile CEC can be calculated, and the corrected CEC of the clay be determined. Uniform clay mineralogy throughout tile profile should be assumed.

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).

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

[5] 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 chrome upon moistening. Such albic horizons occur frequently in, for example, the southern African region.

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 x 10 hand-lens to verify if coatings on sand and silt-sized particles are absent.

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 (r) *vitric* horizon (r) *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 chrome, 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 *sil-andic* type), and one in which aluminium complexed by organic acids prevails (the *alu-andic* type). The sil-andic horizon has an acid to neutral soil reaction, while the alu-andic 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} + $1/2Fe_{ox}$[6] value in the fine earth fraction of 2 percent or more; ***and***

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

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.

Sil-andic 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}[7]/Al_{ox} ratio of less than

0.5 and 0.5 or more, respectively).

[7] Al_{py}: pyrophosphate extractable aluminium.

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.

Sil-andic horizons generally have a field pH (H_2O) of 5 or higher, while alu-andic horizons mainly have a field pH (H_2O) of less than 4.5. If the pH (H_2O) 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 noncrystalline or paracrystalline pedogenetic minerals, as characterized by the moderate amount of acid oxalate (pH 3) extractable aluminium and iron in vitric horizons (Al_{ox} + 1/2Fe_{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} + 1/2Fe_{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 horizon

(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 landscapes 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 (by 1 *M* NH_4OAc) 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 chrome, moist, is more than 3), uniformly structured surface layer, developed through long-continued irrigation with sediment-rich waters. Clay and carbonates are evenly distributed and it has a higher clay content, particularly fine clay, than the underlying original soil. Among the medium, fine and very fine sand fractions relative differences are not larger than 20 percent. It has a weighted average organic carbon content of more than 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 (by 1 *M* NH_4OAc) is less than 50 percent while the P_2O_5 content extractable in 1 percent citric acid is high, at least more than 0.025 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 chrome (moist) of 3 or less. It has a weighted average organic carbon content of 1 percent or more, and 0.5 *M* $NaHCO_3$[8] 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 (by 1 *M* NH_4OAc) is 50 percent or more.

[8] Known as the Olsen routine method (Olsen et al., 1954).

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 (about 60 percent (relative) of the non-capillary porosity of the associated puddled layer).

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:

- layers of 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***
- redox concentrations; ***or***
- redox depletions with a colour value ≥ 4 and chrome ≤ 2 in macropores 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 ferric 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.

Few soil characteristics differentiate the ferric 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 chrome (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:

    a. 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***

    b. 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***

    c. 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. an increase in clay content within a vertical distance of 30 cm if an argic horizon is formed by clay illuviation. In any other case the increase in clay content between the overlying and the argic horizon must be reached within a vertical distance of 15 cm; ***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[9]/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.

[9] Fine clay: <0.2 μm.

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.

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. ***calx***, 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 have:

> 1. calcium carbonate equivalent content in the fine earth fraction of 15 percent or more (for hypercalcic horizons more than 50 percent calcium carbonate equivalent in the fine earth fraction); ***and***
>
> 2. thickness at least 15 cm, also for the hypercalcic horizon.

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:

    a. stronger chrome, redder hue, or higher clay content than the underlying horizon; ***or***

    b. 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***

    c. 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. ***either***-cation exchange capacity (by 1 *M* NH_4OAc) of more than 16 $cmol_c$ kg^{-1} clay;
or -an effective cation exchange capacity (sum of exchangeable bases plus exchangeable

acidity in 1 *M* KCl) of less than 12 $cmol_c\ kg^{-1}$ clay;

or -a content of 10 percent or more weatherable minerals in the 50-200 mm fraction[10].

> [10] 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 pm fraction.

6. thickness of at least 15 cm and a base 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.

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 chrome 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[11] (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***

> [11] Reference is made here to the master horizon nomenclature as used in FAO's Guidelines for Soil Profile Description (1990); see Appendix 1).

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 C horizon if the colour requirements are waived because of dark coloured parent materials; ***and***

5. a base saturation (by 1 *M* NH_4OAc) 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.

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.
    a. in the presence of sufficient interstitial soil water, evidence of cryoturbation, frost heave, cryogenic sorting, thermal cracking, or ice segregation; ***or***

    b. 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 microcrystalline forms of silica ("durinodes").

Diagnostic criteria. A duric horizon must:

1. have 10 percent or more (by volume) of durinodes with the following properties:

    a. do not break down in concentrated hydrochloric acid (HCl), but break down in hot concentrated potassium hydroxide (KOH) after treatment with HCl; ***and***

    b. are firm or very firm, and brittle when wet, both before and after treatment with acid; ***and***

    c. 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 spelling 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 info *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 (by 1 *M* NH_4OAc) of 16 $cmol_c$ 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 $cmol_c$ 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 mm 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 $cmol_c$ 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 clayincrease 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 $Al_{ox} + 1/2Fe_{ox} > 0.4$ (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 chrome 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 chrome 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 noncemented 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 at field capacity more than 50 kN m^{-1}; ***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 peas can have a relative high total porosity, including pores larger than 200 mm, but as a result of a dense outer rim of the peas 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 peas, a concomitant iron accumulation is observed at the level of the ped surface and manganese accumulations will occur further inside the peas (*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.

Fluvic 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 chrome of 2 or less; ***and***

3. a melanic index[12] of more than 1.7 throughout; ***and***

   [12] See Honna *et al*. (1988).

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.

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 $cmol_c\ kg^{-1}$ soil, and the equivalent weight of gypsum (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.

   either - 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 20 percent (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)

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 chrome of 2 or less, ***and***

3. a melanic index[13] of 1.70 or less throughout; ***and***

   [13] See Honna *et al*. (1988).

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.

Mollic horizon

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 chrome 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 immediately 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 (by 1 *M* NH_4OAc) of 50 percent or more on a weighted average throughout the depth of the horizon; ***and***

5. the following thickness:

    a. 10 cm or more if resting directly on hard rock, a *petrocalcic*, *petroduric* or *petrogypsic* horizon, or overlying a *cryic* horizon; ***or***

    b. 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***

    c. 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 percent 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:

   a. 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***

   b. 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***

   c. 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[14]) 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 within 200 cm of the surface; ***and***

   [14] ESP = exchangeable Na x 100/CEC.

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 (H_2O) is more than 8.5.

Additional characteristics. Natric horizons are characterized by a high pH (H_2O) 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 $cmol_c$ 1^{-1} or more. The SAR is calculated from soil solution data: SAR = Na^+ / $[(Ca^{2+} + Mg^{2+}) / 2]^{0.5}$ $cmol_c$/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.

    a. more than 30 percent clay; ***and***

    b. water-dispersible clay/total clay ratio less than 0.10 (unless there is more than 0.6 percent organic carbon); ***and***

    c. 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. Munsell colour value of 5 or less, and chrome of 4 or less, but no mottling of hydromorphic nature (*gleyic* or *stagnic* properties); ***and***

5.

    a. 4.0 percent or more citrate-dithionite extractable iron ("free" iron) in the fine earth fraction; ***and***

b. more than 0.20 percent acid oxalate (pH 3) extractable iron ("active" iron) in the fine earth fraction; ***and***

c. 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 chrome 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 (by 1 *M* NH_4OAc), corrected for organic matter, is less than 36 $cmol_c$ kg^{-1} clay, and often below 24 $cmol_c$ 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.

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Ochric horizon

General description. The ochric horizon (from Gr. ***ochros***, pale) is a surface horizon lacking fine stratification and which is either light coloured[15], or thin, or has an low organic carbon content, or is massive and (very) hard when dry.

> [15] 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 Croup, 1991) it is defined on the second (family) level of classification as a bleached (orthic) A horizon.
>
> 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.

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 30 cm 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 chrome of 3.5 or more when moist, a value of 3.5 or more when moist and 5.5 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:

    a. less than 10 cm if resting directly on hard rock, a *petrocalcic*, *petroduric* or *petrogypsic* horizon, or overlying a *cryic* horizon; ***or***

    b. 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***

    c. 25 cm or less where the solum is more than 75 cm thick.

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. ***calx***, 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 $cmol_c\ kg^{-1}$ 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.
    a. 10 percent (by weight) or more citrate-dithionite extractable iron, at least in the upper part of the horizon; ***and***

    b. ratio between acid oxalate (pH 3) extractable iron and citrate-dithionite extractable iron of less than 0.10[16]; ***and***

    [16] Estimated from data given by Varghese and Byju (1993).

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.

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.

    a. 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***

    b. ratio between acid oxalate (pH 3) extractable iron and citrate-dithionite extractable iron of less than 0.10[17]; ***and***

    [17] Estimated from data given by Varghese and Byju (1993).

    c. less than 0.6 percent (by weight) organic carbon; ***and***

    d. 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.

    a. 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***

b. an EC of more than 8 dS m^{-1} at 25°C if the pH (H_2O) of the saturation extract exceeds 8.5 (for alkaline carbonate soils) or less than 3.5 (for acid sulphate soils); ***and***

2. minimally 1 percent salt; ***and***

3. product of thickness (in cm) times salt percentage of 60 or more; ***and***

4. 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. ***either***- a Munsell hue of 7.5YR or redder with value of 5 or less and chrome of 4 or less when moist and crushed;

or - a hue of 10YR with value of 3 or less and chrome of 2 or less when moist and crushed; ***or***

b. 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***

c. distinct organic pellets between sand grains; ***and***

2. 0.6 percent or more organic carbon; ***and***

3. pH (1:1 in water) of 5.9 or less; ***and***

4.

a. at least 0.50 percent Al_{ox} + ½Fe_{ox}[18] and have two times or more Al_{ox} + ½Fe_{ox} than an overlying *umbric*, *ochric*, *albic* or *anthropedogenic* horizon; ***or***

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

b. an optical density of the oxalate extract (ODOE) value 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.

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. pH < 3.5 in a 1:1 water suspension; ***and***

2.

a. ***either***- 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 chrome of 6 or more; ***or***

b. superposition on *sulfidic* soil materials; ***or***

c. 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:
   a. enough thickness so that it does not curl entirely upon drying;
   b. polygonal desiccation cracks extending at least 2 cm deep when the soil is dry;
   c. sandy clay loam, clay loam, silty clay loam or finer texture;
   d. very hard dry consistence and very plastic and sticky wet consistence; ***and***
   e. an electrical conductivity (EC) in the saturated paste of less than 4 dS m^{-1}, or less than that of the horizon immediately below the takyric horizon.

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 chrome 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 (by 1 *M* NH_4OAc) 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:

    a. 10 cm or more if resting directly on hard rock, a *petroplinthic* or *petroduric* horizon, or overlying a *cryic* horizon; ***or***

    b. 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***

    c. 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° and 60° from the horizontal; ***and***
3. intersecting slickensides[19]; ***and***

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

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.

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*** either:

2. less than 10 percent clay in the fine earth fraction; ***or***

3. a bulk density > 0.9 kg dm^3; ***or***

4. Al_{ox} + 1/2Fe_{ox}[20] >0.4 percent; ***or***

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

5. phosphate retention > 25 percent; ***and***

6. 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 x 10 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.

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. a pavement which is varnished or includes wind-shaped gravel or stones ("ventifacts"); ***or***

b. a pavement and a vesicular crust; ***or***

c. a vesicular crust above a platy A horizon, without a pavement.

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.

Diagnostic properties

Ferralic, *geric*, *gleyic* and *stagnic* and *strongly humic* properties as well as *abrupt textural change, continuous hard rock and permafrost* are retained from the Revised Legend of the Soil Map of the World (FAO, 1988) as they reflect specific soil conditions rather than horizons. The term *secondary carbonates* is preferred to soft powdery lime as used in the Revised Legend. Newly defined diagnostic properties are *albeluvic tonguing*, *alic* and *aridic* properties.

Abrupt textural change

General description. An abrupt textural change is a very sharp increase in clay content within a limited depth range.

Diagnostic criteria. An abrupt textural change requires *either*:

1. doubling of the clay content within 7.5 cm if the overlying horizon has less than 20 percent clay; ***or***

2. 20 percent (absolute) clay increase within 7.5 cm if the overlying horizon has 20 percent or more clay. In this case some part of the lower horizon should have at least twice the clay content of the upper horizon.

Albeluvic tonguing

General description. The term albeluvic tonguing (from L. ***albus***, white, and ***eluere***, to wash out) is connotative of penetrations of clay and iron-depleted material into an *argic* horizon. When peas are present, albeluvic tongues occur along ped surfaces. Redoximorphic characteristics and *stagnic* properties are not necessarily present.

Diagnostic criteria. Albeluvic tongues must:

1. have the colour of an albic horizon; ***and***

2. have greater depth than width, with the following horizontal dimensions:

   a. 5 mm or more in clayey argic horizons; ***or***
   b. 10 mm or more in clay loamy and silty argic horizons; ***or***
   c. 15 mm or more in coarser (silt loam, loam or sandy loam) argic horizons; ***and***

3. occupy more than 10 percent of the volume in the first 10 cm of the *argic* horizon, estimated from or measured on both vertical and horizontal sections; ***and***

4. have a particle size distribution matching that of the eluvial horizon overlying the *argic* horizon.

Alic properties

General description. The term alic properties (from L. ***alumen***, alum) is connotative of very acid mineral soil material with a high amount of exchangeable aluminium.

Diagnostic criteria. Alic properties apply to mineral soil material which has **all** of the following physical and chemical characteristics:

1. a cation exchange capacity (by 1 *M* NH_4OAc) equal to or more than 24 $cmol_c\ kg^{-1}$ clay; ***and***

2.

   a. a total reserve in bases (TRB = exchangeable **plus** mineral Ca, Mg, K and Na) of the clay which is 80 percent or more of the TRB of the soil; ***or***

   b. a silt/clay ratio of 0.60 or less; ***and***

3. a pH (KCl) of 4.0 or less; ***and***

4. a KCl extractable Al content of 12 $cmol_c\ kg^{-1}$ clay or more, and an KCl extractable Al/CEC_{clay}[21] ratio of 0.35 or more; ***and***

> [21] CEC_{clay}: cation exchange capacity (by 1 *M* NH_4OAc) of tile clay fraction, corrected for organic matter.

5. an aluminium saturation (exch. Al/ECEC x 100) of 60 percent or more.

Aridic properties

General description. The term aridic properties combines a number of properties which are common in surface horizons of soils occurring under arid conditions and where pedogenesis exceeds new accumulation at the soil surface by aeolian or alluvial activity.

Diagnostic criteria. Aridic properties are characterized by all of the following:

1. organic carbon content of less than 0.6 percent[22] if texture is sandy loam or finer, or less than 0.2 percent if texture is coarser than sandy loam, as a weighted average in the upper 20 cm of the soil or down to the top of a B horizon, a cemented horizon, or to rock, whichever is shallower; ***and***

> [22] The organic carbon content may be higher if the soil is periodically flooded, or if it has an electrical conductivity of the saturated paste extract of 4 $dS\ m^{-1}$ or more somewhere within 100 cm of the soil surface.

2. evidence of aeolian activity in one or more of the following forms:

   a. the sand fraction in some subhorizon or in inblown material filling cracks contains a noticeable proportion of rounded or subangular sand particles showing a matt surface (use a x 10 hand-lens). These particles make up 10 percent or more of the medium and coarser quartz sand fraction; ***or***

   b. wind-shaped rock fragments ("ventifacts") at the surface; ***or***

   c. aeroturbation (e.g. crossbedding); ***or***

   d. evidence of wind erosion or deposition, or both; ***and***

3. both broken and crushed samples have a Munsell colour value of 3 or more when moist and 4.5 or more when dry, and a chrome of 2 or more when moist; ***and***

4. base saturation (by 1 *M* NH_4OAc) of more than 75 percent, but normally 100 percent.

Additional remarks. The presence of acicular ("needle-shaped") clay minerals (e.g. palygorskite and sepiolite) in soils is considered connotative of a desert environment, but it has not been reported in all desert soils. This may be due to the fact that under arid conditions acicular clays are not produced but only preserved, provided they exist in the parent material or in the dust that falls on the soil.

Continuos hard rock

Definition. Continuous hard rock is material underlying the soil, exclusive of cemented pedogenetic horizons such as a *petrocalcic, petroduric, petrogypsic* and *petroplinthic* horizons, which is sufficiently coherent and hard when moist to make hand digging with a spade impractible. The material is considered continuous if only a few cracks 10 cm or more apart are present and no significant displacement of the rock has taken place.

Ferralic properties

General description. Ferralic properties (from L. ***ferrum***, iron, and ***alumen***, alum) refer to mineral soil material which has a relative low cation exchange capacity. It also includes soil materials which would qualify for a *ferralic* horizon apart for their coarse texture.

Diagnostic characteristics. Ferralic properties apply to mineral soil materials which have *either*:

1. a cation exchange capacity (by 1 *M* NH_4OAc) of less than 24 $cmol_c$ kg^{-1} clay; ***or***

2. a cation exchange capacity (by 1 *M* NH_4OAc) of less than 4 $cmol_c$ kg^{-1} soil, both in at least some subhorizon of the B horizon or the horizon immediately underlying the A horizon.

Geric properties

General description. Geric properties (from Gr. ***geraios***, old) refers to mineral soil material which has a very low effective cation exchange capacity or even acts as an anion exchanger.

Diagnostic criteria. Mineral soil material has geric properties if it has ***either***:

1. 1.5 $cmol_c$ or less of exchangeable bases (Ca, Mg, K, Na) plus unbuffered 1 *M* KCl exchangeable acidity per kg clay; ***or***

2. a delta pH (pH_{KCl} minus pH_{water}) of +0.1 or more.

Gleyic properties

General description. Soil materials develop gleyic properties (from the Russian local name ***gley***, mucky soil mass) if they are completely saturated with groundwater, unless drained, for a period that allows **reducing conditions** to occur (this may range from a few days in the tropics to a few weeks in other areas), and show a **gleyic colour pattern**.

Diagnostic criteria. Reducing conditions[23] are evident by:

1. a value of rH in the soil solution of 19 or less; ***or***

2. the presence of free Fe^{2+} as shown by the appearance of either:

    a. a solid dark blue colour on a freshly broken surface of a field-wet soil sample, after spraying it with a potassium ferric cyanide ($K_3Fe(III)(CN)_6$) solution; ***or***

    b. a strong red colour on a freshly broken surface of a field-wet soil sample after spraying it with a a,a, dipyridyl solution in 10% acetic acid; ***and***

3. a gleyic colour pattern[24] reflecting oxirnorphic[25] and/or reductomorphic[26] properties ***either***:

a. in more than 50 percent of the soil mass; ***or***
b. in 100 percent of the soil mass below any surface horizon.

[23] The basic measure for reduction in soil materials is the rH. This measure is related to the redox potential (Eh) and corrected for the pH as shown in the following formula:

$$rH = \frac{Eh(mV)}{29} + 2pH$$

[24] *A gleyic colour pattern* results from a redox gradient between the groundwater and capillary fringe causing an uneven distribution of iron and manganese (hydr)oxides. In the lower part of the soil and/or inside the peas the oxides are either transformed into insoluble Fe/Mn(II) compounds or they are translocated both processes leading to the absence of colours with a Munsell hue redder than 2.5Y. Translocated iron and manganese compounds can be concentrated in oxidized form (Fe(III) Mn(lV)) recognizable by a 10% H_2O_2 test in the field on ped surfaces or in (bio)pores ("rusty root channels"), and towards the surface even in the matrix.

[25] *Oximorphic properties* reflect alternating reducing and oxidizing conditions as is the case in the capillary fringe and in the surface horizon(s) of soils with fluctuating groundwater levels. Oximorphic properties are expressed by reddish brown (ferrihydrite) or bright yellowish brown (goethite) mottles or as bright yellow (jarosite) mottles in acid sulphate soils. In loamy and clayey soils the iron (hydr)oxides are concentrated on aggregate surfaces and the walls of larger pores (e.g. old root channels).

[26] *Reductomorphic properties* reflect permanently wet conditions and are expressed by neutral (white to black: N1/ to N8/) or bluish to greenish (2.5Y, 5Y, 5G, 5B) colours in more than 95 percent of the soil matrix. In loamy and clayey material blue-green colours dominate due to Fe (II,III) hydroxy salts (green rust). If the material is rich in sulphur blackish colours prevail due to iron sulphides. In calcareous material whitish colours are dominant due to calcite and/or siderite. Sands are usually light grey to white in colour and often also impoverished in iron and manganese.

The upper part of a reductomorphic horizon may show up to 5 percent rusty colours mainly around channels of burrowing animals or plant roots.

Field identification. Iron and manganese (hydr)oxides in soils with gleyic properties are redistributed to the outside of the peas and towards the soil surface from where oxygen is derived. The resulting colour pattern (reddish, brownish or yellowish colours near the ped surface or in the upper part of the profile, together with grayish/bluish colours in the inside of the peas or deeper in the soil) indicates if gleyic conditions occur. Also, the dipyridyl test often gives a good indication if ferric iron is present in the soil solution.

Permafrost

Definition. Permafrost is a layer in which the temperature is perennially at or below 0°C for at least two consecutive years.

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Secondary carbonates

General description. The term secondary carbonates refers to translocated lime, soft enough to be cut readily with a finger nail, precipitated in place from the soil solution rather than inherited from a soil parent material. As a diagnostic property it should be present in significant quantities.

Field identification. Secondary carbonates must have some relation to the soil structure or fabric. Secondary carbonate accumulations may disrupt the fabric to form spheroidal aggregates or 'white eyes', that are soft and powdery when dry, or lime may be present as soft coatings in pores or on structural faces. If present as coatings, secondary carbonates cover 50 percent or more of the structural faces and are thick enough to be visible when moist. If present as soft nodules, they occupy 5 percent or more of the soil volume. Filaments (pseudomycelia), which come and go with changing moisture conditions, are not included in the definition of secondary carbonates.

Stagnic properties

General description. Soil material has stagnic properties (from L. ***stagnare***, to flood) if it is, at least temporarily, completely saturated with surface water, unless drained, for a period long enough to allow **reducing conditions** to occur (this may range from a few days in the tropics to a few weeks in other areas), and show a **stagnic colour pattern**[27].

> [27] *A stagnic colour pattern* shows mottling in such a way that the surfaces of the peas (or part of the soil matrix) are lighter (one Munsell value unit or more) and paler (one chrome unit or less) coloured, and the interior of the peas (or parts of the soil matrix) are more reddish (one hue unit or more) and brighter (one chrome unit or more) coloured than the non-redoximorphic parts of the layer, or of its mixed average. This mottling pattern may occur directly below the surface horizon or plough layer, or below an albic horizon.

Diagnostic criteria. Reducing conditions are evident by:

1. a value of rH in the soil solution of 19 or less; ***or***

2. the presence of free Fe^{2+} as shown by the appearance of ***either***:

    a. a solid dark blue colour on a freshly broken surface of a field-wet soil sample, after spraying it with a 1% potassium ferric cyanide ($K_3Fe(III)(CN)_6$) solution; ***or***

    b. a strong red colour on a freshly broken surface of a field-wet soil sample after spraying it with a 0.2% a,a, dipyridyl solution in 10% acetic acid; ***and***

3. an *albic* horizon or a stagnic colour pattern ***either***:

    a. in more than 50 percent of the soil volume if the soil is undisturbed; ***or***
    b. in 100 percent of the soil volume if the surface horizon is disturbed by ploughing.

Field identification. The distribution pattern of the redoximorphic features, with iron and manganese oxides concentrated in the inside of peas (or in the matrix if peas are absent) gives a good indication of stagnic properties.

Strongly humic properties

General description. Strongly humic properties refer to soils which have a high organic carbon content in the upper metre of the soil.

Diagnostic criteria. To be strongly humic, soil material must have more than 1.4 percent organic carbon as weighted average over a depth of 100 cm from the soil surface (the same weighted average over 100 cm applies if the soil is 50-100 cm deep; soils less than 50 cm deep cannot be strongly humic). The calculation assumes a bulk density of 1.5 g cm^{-3}.

Diagnostic materials

It appeared appropriate to define diagnostic soil materials. These diagnostic soil materials are intended to reflect the original parent materials, in which pedogenetic processes have not yet been so active that they have left a significant mark. They comprise *anthropogenic*, *calcaric*, *fluvic*, *gypsiric*, *organic*, *sulfidic* and *tephric* soil material. The *fluvic*, *calcareous* and *calcaric*, and *gypsiferous* properties of the Revised Legend (FAO, 1988) are redefined under *fluvic*, *calcaric* and *gypsiric* soil material.

Anthropogeomorphic soil material

General description. Anthropogeomorphic soil material (from Gr. ***anthropos***, human) refers to unconsolidated mineral or organic material resulting largely from land fills, mine spoil, urban fill, garbage dumps, dredgings, etc., produced by human activities. It has, however, **not** been subject to a sufficiently long period of time to find significant expression of pedogenetic processes.

Descriptions of some anthropogeomorphic soil materials are given in Table 2.

TABLE 2 **Some anthropogeomorphic soil materials**

Aria	Mineral soil material which has, in one or more layers between 25 and 100 cm from the soil surface, 3 percent or more (by volume) fragments of diagnostic horizons which are not arranged in any discernible order.
Garbic	Organic waste material; land fill containing dominantly organic waste products.

Reductic	Waste products producing gaseous emissions (e.g. methane, carbon dioxide) resulting in anaerobic conditions in the material.
Spolic	Earthy material resulting from industrial activities (mine spoil, river dredgings, highway constructions, etc.).
Urbic	Earthy material containing building rubble and artifacts (cultural debris > 35 percent by volume).

Calcaric soil material

Definition. Calcaric soil material (from En. calcareous) shows strong effervescence with 10 percent HCl in most of the fine earth. It applies to material which contains more than 2 percent calcium carbonate equivalent.

Fluvic soil material

General description. Fluvic soil material (from L. ***fluvius***, river) refers to fluviatile, marine and lacustrine sediments, which receive fresh material at regular intervals, or have received it in the recent past[28].

> [28] Recent past covers the period during which the soil has been protected from flooding, e.g. by empoldering, embanking, canalization or artificial drainage, and during which time soil formation has not resulted in the development of any diagnostic subsurface horizon apart from a *salic* or *sulfuric* horizon.

Diagnostic criteria. Fluvic soil material is soil material which shows stratification in at least 25 percent of the soil volume over a specified depth; stratification may also be evident from an organic carbon content decreasing irregularly with depth, or remaining above 0.2 percent to a depth of 100 cm. Thin strata of sand may have less organic carbon if the finer sediments below, exclusive of buried A horizons, meet the latter requirement.

Field identification. Fluvic soil material shows stratification. Alternating darker coloured soil layers may reflect an irregular decrease in organic carbon content with depth.

Gypsiric soil material

Definition. Gypsiric soil material (from L. ***gypsum***) is mineral soil material which contains 5 percent or more gypsum (by volume).

Organic soil material

General description. Organic soil material consists of organic debris which accumulates at the surface under either wet or dry conditions and in which the mineral component does not significantly influence the soil properties.

Diagnostic criteria. Organic soil material must have one of the two following:

> 1. if saturated with water for long periods (unless artificially drained), and excluding live roots, ***either***:

a. 18 percent organic carbon (30 percent organic matter) or more if the mineral fraction comprises 60 percent or more clay; ***or***

b. 12 percent organic carbon (20 percent organic matter) or more if the mineral fraction has no clay; ***or***

c. 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; ***or***

2. if never saturated with water for more than a few days, 20 percent or more organic carbon.

Sulfidic soil material

General description. Sulfidic soil material (from E. ***sulphide***) is waterlogged deposit containing sulphur, mostly in the form of sulphides, and only moderate amounts of calcium carbonate.

Diagnostic criteria. Sulfidic soil material must have:

1. 0.75 percent or more sulphur (dry weight) and less than three times as much calcium carbonate equivalent as sulphur; ***and***

2. pH (H_2O) of more than 3.5.

Field identification. Deposits containing sulphides often show in moist or wet condition a golden shine, the colour of pyrite. Forced oxidation with a 30 percent hydrogen peroxide solution lowers the pH by 0.5 unit or more. Oxidation also gives rise to the smell of rotten eggs.

Tephric soil material

Tephric soil material[29]

[29] Description and diagnostic criteria are adapted from Hewitt (1992).

General description. Tephric soil material (from Gr. ***tephra***, pile ash) consists either of **tephra**, i.e. unconsolidated, non or only slightly weathered primary pyroclastic products of volcanic eruptions (including ash, cinders, lapilli, pumice, pumice-like vesicular pyroclastics, blocks or volcanic bombs), or of **tephric deposits**, i.e. tephra which has been reworked and mixed with material from other sources. This includes tephric loess, tephric blown sand and volcanogenic alluvium.

Diagnostic criteria. Tephric soil material must have:

1. 60 percent or more tephra; ***and***
2. less than 0.4 percent Al + 1/2Fe, both extractable in acid oxalate (pH 3).

Relationships with some diagnostic horizons. The low amount of acid oxalate extractable aluminium and iron sets tephric soil material apart from *vitric* horizons.

Chapter 4: Classifying subdivisions of the reference soil groups

Since the inception of the Legend of the Soil Map of the World (FAO, 1974), the number of lower level units used in the Legend or soil classification has continued to grow: from 106 in 1974 to 152 in the Revised Legend of the Soil Map of the World (FAO, 1988) to 209 in the first draft of the *World Reference Base for Soil Resources* (ISSS-ISRIC-FAO, 1994). At the same time a serious effort was undertaken to expand this second level further with the introduction of third level units (Nachtergaele et al., 1994). Further proliferation of soil units and subunits in the World Reference Base might easily lead to a situation where it will become extremely difficult to recall and use all definitions within the main reference soil groups.

A further complication is that many soil unit names, and modifiers in the draft WRB, were inherited from the original FAO Legend and were defined depending on the grouping in which they occurred. For example, a "Dystric" soil unit may mean: "... having a base saturation of less than 75%" (in Dystric Vertisols), or "... having a base saturation of less than 50%", in different control sections (e.g. note the difference in control sections of Dystric Planosols and Dystric Cambisols).

Another limitation inherent to the close link with the Legend of the Soil Map of the World is that, although often used as a soil classification system, the original purpose of the FAO system was to serve as a Legend for a specific map, which made certain simplifications necessary. For example, Calcic Gleysols included soil with a gypsic horizon. Similarly, Umbric Fluvisols grouped alluvial soils with an umbric horizon together with Fluvisols with a desaturated histic horizon. This resulted in loss of information due to the generalization required for the Legend.

Last but not least, it is thought that a clear-cut separation must be made between the double objectives of the World Reference Base, which on one hand should be able to serve as a soil reference system for geographers, agronomists and other users who are mainly interested in the highest level of generalization explained in non-technical terms, while on the other hand WRB must be a sophisticated tool for soil correlation able to accommodate a wide range of national soil classification systems.

In order to remedy the soil classification constraints as discussed above, it is decided to aim for standardized definitions for each subdivision and to design a flexible soil classification system which allows for a maximum transfer of soil profile information. Therefore a limited number of names are defined for the subdivisions of the World Reference Base soil groups which may be used in a certain ranking order to qualify each group at lower levels. Moreover, to simplify its use as far as possible, a unique definition for each qualifier, as well as the use of standard depths and thicknesses, is promoted. In doing so, it is unavoidable that the certain link which now existed until 1994 with the FAO soil units will be partly lost. However, this loss is compensated by the gain of clarity and ease of use of the present approach.

A further advantage of standardized subdivisions is that it will facilitate and enhance soil correlation and technology transfer among countries and regions. It should, in addition, serve useful purposes (for example land evaluation and land use planning), and should not be considered as an end in itself but rather contribute to the better understanding of the soil resource.

At this stage it is not possible to provide a comprehensive list of lower level names for the World Reference Base. Reviewing the uses which have been made of at second level by FAO (1988), Soil Survey Staff (1996) and WRB (ISSS-ISRIC-FAO, 1994), and at third level in soil classifications of Botswana (Remmelzwaal and Verbeek, 1990), northeastern Africa (FAO, 1998), Bangladesh (Brammer *et al*, 1988) and the European Union (CEC, 1985), and by reclassifying a large number of typifying pedons of all reference soil groups, a provisional list of names and definitions has been established.

General principles for distinguishing lower level units

In order to keep the system simple and easy to use, criteria to differentiate soil subunits are selected that closely relate to the diagnostic criteria defined at the first level.

The newly introduced criteria relate to additional soil properties which are thought to be relevant at lower levels. The use of phases as differentiating criteria of the lower classification levels should, in principle, be kept at minimum. A few of them, however, have been included in the provisional list of names.

General rules

The general rules to be followed when differentiating lower level units are:

1. The diagnostic criteria applied at lower level are derived from the already established reference group diagnostic horizons, properties and other defined characteristics. They may, in addition, include new elements as well as criteria used for phase definitions at higher levels.

2. Lower level units may be defined, and named, on the basis of the presence of diagnostic horizons. In general, weaker or incomplete occurrences of similar features are not considered as differentiae.

3. Differentiating criteria related to climate, parent material, vegetation or to physiographic features such as slope, geomorphology or erosion are not considered. The same applies to criteria derived from soil-water relationships such as depth of water table or drainage. Substratum layers, thickness and morphology of solum or individual horizons, are not considered as diagnostic criteria for the differentiation of the lower level units.

4. There is one set of diagnostic criteria for the definition of the lower level soil units. This name contains in its definition the diagnostic criterion and functions at the same time as second and third level connotative. Each soil qualifier is given one unique meaning which should be applicable to all reference soil groups in which it occurs.

5. A single name should be used to define each lower level. However, these names can be used in combination with indicators of depth, thickness or intensity. If additional names are

needed, these should be listed after the reference soil group names between brackets, e.g. Acri-Geric Ferralsol (Abruptic and Xanthic).

6. Definitions of the lower level units should not overlap or conflict with other soil subunits or with reference soil group definitions. For example, a Dystri-Petric Calcisol is a contradiction, whereas a Eutri-Petric Calcisol is an overlap in the sense that the name "eutric" does not give more information.

New units can only be established after being documented by soil profile descriptions and supporting laboratory analyses.

7. Priority rules for the use of lower level soil names are to be followed strictly to avoid confusion. Precise ranking orders for each qualifier in each reference soil group are given later in the text.

Example

In Vertisols the following qualifiers have been recognized, in order of priority:

1.	Thionic	intergrade with acid sulphate Gleysols and Fluvisols
2.	Salic	intergrade with the Solonchak reference soil group
3.	Natric	intergrade with the Solonetz reference soil group
4.	Gypsic	intergrade with the Gypsisol reference soil group
5.	Duric	intergrade with the Durisol reference soil group
6.	Calcic	intergrade with the Calcisol reference soil group
7.	Alic	intergrade with the Alisol reference soil group
8.	Gypsiric	containing gypsum
9.	Pellic	dark coloured, often poorly drained
10.	Grumic	mulched surface horizon
11.	Mazic	very hard surface horizon; workability problems
12.	Chromic	reddish coloured
13.	Mesotrophic	having less than 75 percent base saturation (occurs in Venezuela)
14.	Hyposodic	having an ESP of 6 to 15
15.	Eutric	having 75 percent or more base saturation
16.	Haplic	no specific characteristics

To classify a reddish coloured *Vertisol* with a calcic horizon one would follow the priority list and note that qualifiers 6 and 12 apply. Therefore, the soil is classified as Chromi-Calcic Vertisol. If more information on depth and intensity of the calcic horizon is available, e.g. Occurring near to the surface, one may specify this by classifying the soil as Chromi-Epicalcic Vertisol, indicating the occurrence of the calcic horizon within 50 cm from the surface.

When more than two qualifiers are required, they can be added between brackets after the standard name. If, for instance, the Vertisol discussed also has a very hard surface horizon (qualifier 11), the soil would be named Mazi-Calcic Vertisol (Chromic).

Future expansion and applications

This system allows a maximum transfer of soil knowledge because all qualifiers have a unique meaning, are relatively few in number, and can easily be taught and memorized.

When used for mapping purposes at different levels of detail in combination with existing national soil classification systems, the system will need to be adapted to serve as a legend for soil maps. This may require a simplification and grouping several of the qualifiers together. For example, in the list of qualifiers the name "Thionic" already combines "Protothionic" and "Orthithionic"; another example would be to consider only intergrade names for a small-scale map.

It should also be noted that in the ongoing preparation of a World Soil and Terrain Database by UNEP, ISSS, ISRIC and FAO (Van Engelen & Wen, 1995; Nachtergaele, 1996), mapping units also contain soil profile information which can be classified using the present system.

It is also realized that for soil management purposes often more information is required, in particular on topsoil characteristics and on soil climate. It is proposed that guidelines on both issues should be further developed in line with existing proposals such as "The Characterization of Topsoils" (Fitzpatrick, 1988; Spaargaren, 1992; Purnell *et al*., 1994), and the climatic regimes of the Global Agro-ecological Zones Methodology (Fisher *et al*., 1996).

Definitions of formative elements for lower level units

The definitions of diagnostic horizons and properties, given in italics below, are those presented in Chapter 3, unless stated otherwise.

In most situations only a limited number of combinations will be possible, as most of the definitions are mutually exclusive.

TABLE 3 **Alphabetical list of lower level soil names**

	Abruptic		Ferralic		Lixic		Rhodic
	Aceric		Ferric		Luvic		Rubic
	Acric		Fibric		Magnesic		Ruptic
	Acroxic		Folic		Mazic		Rustic
	Albic		Fluvic		Melanic		Salic
	Alcalic		Fragic		Mesotrophic		Sapric
	Alic		Fulvic		Mollic	100	Silic
	Alumic		Garbic	70	Natric		Siltic
	Andic	40	Gelic		Nitic		Skeletic
10	Anthraquic		Gelistagnic		Ochric		Sodic
	Anthric		Geric		Ombric		Spodic
	Anthropic		Gibbsic		Oxyaquic		Spolic
	Arenic		Glacic		Pachic		Stagnic
	Aric		Gleyic		Pellic		Sulphatic
	Aridic		Glossic		Petric		Takyric
	Arzic		Greyic		Petrocalcic		Tephric
	Calcaric		Grumic		Petroduric	110	Terric
	Calcic		Gypsic	80	Petrogypsic		Thionic
	Carbic	50	Gypsiric		Petroplinthic		Toxic
20	Carbonatic		Haplic		Petrosalic		Turbic
	Chernic		Histic		Placic		Umbric
	Chloridic		Hortic		Plaggic		Urbic
	Chromic		Humic		Planic		Vetic
	Cryic		Hydragric		Plinthic		Vermic
	Cutanic		Hydric		Posic		Vertic
	Densic		Hyperochric		Profondic		Vitric

	Duric		Hyperskeletic		Protic	120	Xanthic
	Dystric		Irragric	90	Reductic		Yermic
	Entic	60	Lamellic		Regic		
30	Eutric		Leptic		Rendzic		
	Eutrisilic		Lithic		Rheic		
Where relevant, the names can be defined further using prefixes, for example Epigleyi-, Protothioni-. The following prefixes can be used:							
	Bathi		Epi		Orthi		Thapto
	Cumuli		Hyper		Para		
	Endo		Hypo		Proto		

Abruptic	having an *abrupt textural change.*
Aceric	having a pH (1:1 in water) between 3.5 and 5 and jarosite mottles within 100 cm from the soil surface (*in Solonchaks only*).
Acric	having a *ferralic* horizon which meets the clay increase requirements of an *argi* some horizon, and which has a base saturation (by 1 *M* NH_4OAc) of less than 50 percent in at least part of the B horizon within 100 cm from the soil surface (*in Ferralsols only*).
Acroxic	having less than 2 $cmol_c\ kg^{-1}$ fine earth exchangeable bases plus 1 *M* KCl exchangeable Al^{3+} in one or more horizons with a combined thickness of 30 cm or more within 100 cm from the soil surface (*in Andosols only*).
Albic	having an *albic* horizon within 100 cm from the soil surface.
Hyperalbic	having an *albic* horizon within 50 cm from the soil surface and the lower boundary at a depth of 100 cm or more from the soil surface.
Glossalbic	showing tonguing of an *albic* into an argic or *natric horizon*.
Alcalic	having a pH (1:1 in water) of 8.5 or more within 50 cm from the soil surface.
Alic	having an *argic* horizon which has a cation exchange capacity equal to or more than 24 $cmol_c\ kg^{-1}$ clay throughout, a silt/clay ratio of less than 0.6, and an Alsaturation of 50 percent or more.
Alumic	having an Al-saturation of 50 percent or more in at least some part of the B horizon between 50 and 100 cm from the soil surface.
Andic	having an *andic* horizon within 100 cm from the soil surface.
Aluandic	having an *andic* horizon with an acid oxalate (pH 3) extractable silica content of less than 0.6 percent, or an Al_{py}[30]/Al_{ox}[31] ratio of 0.5 or more. [30] Al_{py} pyrophosphate extractable aluminium. [31] Al_{ox}: acid oxalate (pH 3) extractable aluminium (method of Blakemore *et al*, 1981).
Silandic	having an *andic* horizon with an acid oxalate (pH 3) extractable silica content of 0.6 percent or more, or an Al_{py}/Al_{ox} ratio of less than 0.5.

Anthraquic	having an *anthraquic* horizon.
Anthric	showing evidence of human influence caused by cultivation practices.
Anthropic	consisting of *anthropogeomorphic* soil material, or showing profound modification of the soil by human activity caused by other factors than those related to cultivation (*in Regosols only*).
Aric	having only remnants of diagnostic horizons caused by repeated deep ploughing.
Arenic	having a texture of loamy fine sand or coarser throughout the upper 50 cm of the soil.
Aridic	having aridic properties without a takyric or yermic horizon.
Arzic	having sulphate-rich groundwater within 50 cm from the soil surface at some period in most years and containing 15 percent or more gypsum averaged over a depth of 100 cm (*in Gypsisols only*).
Calcaric	calcareous at least between 20 and 50 cm from the soil surface.
Calcic	having a *calcic* horizon or concentrations of secondary carbonates between 50 and 100 cm from the soil surface.
Hypercalcic	having a *calcic* horizon which contains 50 percent or more calcium carbonate equivalent.
Hypocalcic	having only concentrations of *secondary carbonates* within 100 cm from the soil surface.
Orthicalcic	having a *calcic* horizon within 100 cm from the soil surface.
Carbic	having a cemented *spodic* horizon which does not contain enough amorphous iron to turn redder on ignition (*in Podzols only*).
Carbonatic	having a soil solution with pH > 8.5 (1:1 in water) and $HCO_3 > SO_4 >> Cl$ (*in Solonchaks only*).
Chernic	having a *chernic* horizon (*in Chernozems only*).
Chloridic	having a soil solution (1:1 in water) with $Cl >> SO_4 > HCO_3$ (*in Solonchaks only*).
Chromic	having a B horizon which in the major part has a Munsell hue of 7.5YR and a chrome, moist, of more than 4, or a hue redder than 7.5YR.
Cryic	having a *cryic* horizon within 100 cm from the soil surface.
Cutanic	having clay skins in the argic horizon (*in Luvisols only*).
Densic	having a cemented *spodic* horizon ("ortstein") (*in Podzols only*).
Duric	having a *duric* horizon within 100 cm from the soil surface.
Dystric	having a base saturation (by 1 M NH_4OAc) of less than 50 percent in at least some part between 20 and 100 cm from the soil surface, or in a layer 5 cm thick directly above a lithic contact in Leptosols.
Epidystric	having a base saturation (by 1 M NH_4OAc) of less than 50 percent at least between 20 and 50 cm from the soil surface.

Hyperdystric	having a base saturation (by 1 *M* NH_4OAc) of less than 50 percent in all parts between 20 and 100 cm from the soil surface, and less than 20 percent in some part within 100 cm from the soil surface.
Orthidystric	having a base saturation (by 1 *M* NH_4OAc) of less than 50 percent in all parts between 20 and 100 cm from the soil surface.
Entic	lacking an *albic* horizon and having a loose *spodic* horizon (*in Podzols only*).
Eutric	having a base saturation (by 1 *M* NH_4OAc) of 50 percent or more at least between 20 and 100 cm from the soil surface, or in a layer 5 cm thick directly above a lithic contact in Leptosols.
Endoeutric	having a base saturation (by 1 *M* NH_4OAc) of 50 percent or more in all parts between 50 and 100 cm from the soil surface.
Hypereutric	having a base saturation (by 1 *M* NH_4OAc) of 80 percent or more in all parts between 20 and 100 cm from the soil surface.
Orthieutric	having a base saturation (by 1 *M* NH_4OAc) of 50 percent or more in all parts between 20 and 100 cm from the soil surface.
Eutrisilic	having a *sil-andic* horizon and a sum of exchangeable bases of 25 $cmol_c\ kg^{-1}$ fine earth within 30 cm from the soil surface.
Ferralic	having *ferralic* properties within 100 cm from the soil surface.
Hyperferralic	having a cation exchange capacity (by 1 *M* NH_4OAc) of less than 16 $cmol_c\ kg^{-1}$ clay in at least some subhorizons within 100 cm from the soil surface.
Hypoferralic	having a cation exchange capacity (by 1 *M* NH_4OAc) of less than 4 $cmol_c\ kg^{-1}$ fine earth in at least 30 cm of the upper 100 cm of the soil, and a Munsell colour chrome, moist, of 5 or more and/or hues redder than 10YR (*in Arenosols only*).
Ferric	having a *ferric* horizon within 100 cm from the soil surface.
Hyperferric	having one or more layers with a total thickness of 25 cm or more consisting of 40 percent or more iron/manganese-oxide nodules within 100 cm from the soil surface.
Fibric	having more than two-thirds (by volume) of the *organic* soil material consisting of recognizable plant tissue (*in Histosols only*).
Folic	having a *folic* horizon (*in Histosols only*).
Fluvic	haying *fluvic* soil materials within 100 cm from the soil surface.
Fragic	having a *fragic* horizon within 100 cm from the soil surface.
Fulvic	having a *fulvic* horizon within 30 cm from the soil surface.
Garbic	having accumulations of *anthropogeomorphic* soil material containing more than 35 percent (by volume) organic waste materials (*in Anthropic Regosols only*).
Gelic	having *permafrost* within 200 cm from the soil surface.
Gelistagnic	having temporary water saturation at the surface caused by a frozen subsoil.
Geric	having geric *properties* in at least some horizon within 100 cm from the soil surface.

Gibbsic	having a layer more than 30 cm thick containing more than 25 percent gibbsite in the fine earth fraction within 100 cm from the soil surface.
Glacic	having a horizon within 100 cm from the soil surface which is 30 cm or more thick and contains 95 percent or more (by volume) ice.
Gleyic	having *gleyic* properties within 100 cm from the soil surface.
Endogleyic	having *gleyic* properties between 50 and 100 cm from the soil surface.
Epigleyic	having *gleyic* properties within 50 cm from the soil surface.
Glossic	showing tonguing of a *mollic* or *umbric* horizon into an underlying B horizon or into the saprolite.
Molliglossic	showing tonguing of a *mollic* horizon into an underlying B horizon or into the saprolite.
Umbriglossic	showing tonguing of an *umbric* horizon into an underlying B horizon or into the saprolite.
Greyic	having uncoated silt and sand grains on structural pedfaces in a *mollic* horizon (*in Phaeozems only*).
Grumic	having a surface layer with a thickness of 3 cm or more with a strong structure finer than very coarse granular (*in Vertisols only*).
Gypsic	having a *gypsic* horizon within 100 cm from the soil surface.
Hypergypsic	having a *gypsic* horizon which has 60 percent or more gypsum.
Hypogypsic	having a *gypsic* horizon which has 25 percent or less gypsum.
Gypsiric	having *gypsiric* soil material at least between 20 and 50 cm from the soil surface.
Haplic	having a typical expression of certain features (typical in the sense that there is no further or meaningful characterization).
Histic	having a *histic* horizon within 40 cm from the soil surface.
Fibrihistic	having a *histic* horizon within 40 cm from the soil surface, in which more than two-thirds (by volume) of the *organic* soil material consist of recognizable plant tissue.
Saprihistic	having a *histic* horizon within 40 cm from the soil surface, in which less than one-sixth (by volume) of the *organic* soil material consists of recognizable plant tissue and which has a very dark grey to black colour.
Thaptohistic	having a buried *histic* horizon between 40 and 100 cm from the soil surface.
Hortic	having a *hortic* horizon; in *Anthrosols* 50 cm or more thick, in other soils less than 50 cm thick.
Humic	having a high organic carbon content; in *Ferralsols* and *Nitisols* more than 1.4 percent (by weight) organic carbon in the fine earth fraction as weighted average over a depth of 100 cm from the soil surface, in *Leptosols* more than 2 percent (by weight) organic carbon in the fine earth fraction to a depth of 25 cm from the soil surface, and in other soils more than 1 percent (by weight) organic carbon in the fine earth fraction to a depth of 50 cm from the soil surface.
Mollihumic	having the organic carbon content as defined above and a mollic horizon

Umbrihumic	having the organic carbon content as defined above and an *umbric* horizon.
Hydragric	having an *anthraquic* horizon and an associated *hydragric* horizon, the latter occurring within 100 cm from the soil surface (*in Anthrosols only*).
Hydric	having within 100 cm from the soil surface one or more layers with a total thickness of 35 cm or more, which have a water retention at 1500 kPa (in undried samples) of 100 percent or more (*in Andosols only*).
Hyperskeletic	having more than 90 percent (by weight) gravel or other coarse fragments to a depth of 75 cm or to continuous hard rock (*in Leptosols only*).
Irragric	having an *irragric* horizon; in *Anthrosols* 50 cm or more thick, in other soils less than 50 cm thick.
Lamellic	having clay illuviation lamellae with a combined thickness of at least 15 cm within 100 cm from the soil surface.
Leptic	having continuous hard rock between 25 and 100 cm from the soil surface.
Endoleptic	having continuous hard rock between 50 and 100 cm from the soil surface.
Epileptic	having continuous hard rock between 25 and 50 cm from the soil surface.
Lithic	having continuous hard rock within 10 cm from the soil surface.
Paralithic	having within 10 cm from the soil surface a broken rock contact with fissures less than 10 cm apart which allow roots to penetrate the underlying rock.
Lixic	having a *ferralic* horizon which meets the clay increase requirements of an *argic* horizon, and which has a base saturation (by 1 *M* NH_4OAc) of 50 percent or more throughout the B horizon to a depth of 100 cm from the soil surface (*in Ferralsols only*).
Luvic	having an *argic* horizon which has a cation exchange capacity equal to or more than 24 $cmol_c\ kg^{-1}$ clay throughout, and a base saturation by 1 *M* NH_4OAc) of 50 percent or more throughout the horizon to a depth of 100 cm from the soil surface.
Hypoluvic	having an absolute clay increase of 3 percent or more within 100 cm from the soil surface (*in Arenosols only*).
Magnesic	having an exchangeable Ca/Mg ratio of less than 1 within 100 cm from the soil surface.
Mazic	having a massive structure and hard to very hard consistence in the upper 20 cm of the soil (*in Vertisols only*).
Melanic	having a *melanic* horizon (*in Andosols only*).
Mesotrophic	having a base saturation (by 1 *M* NH_4OAc) of less than 75 percent at 20 cm depth (*in Vertisols only*).
Mollic	having a *mollic* horizon.
Natric	having a *natric* horizon within 100 cm from the soil surface.
Nitic	having a *nitic* horizon within 100 cm from the soil surface.
Ochric	having an *ochric* horizon.

Hyperochric	having an *ochric* horizon with a light or bleached colour (commonly grey) in dry state which turns darker on moistening ("bleached surface horizons"), a low (usually <0.4%; South African results) organic carbon content and relatively low free iron oxide content, a coarse texture, signs of a platy structure, and a thin surface crust.
Ombric	having a water regime conditioned by groundwater (*in Histosols only*).
Oxyaquic	saturated with water during the thawing period and lacking redoximorphic features within 100 cm from the soil surface (*in Cryosols only*).
Pachic	having a *mollic* or *umbric* horizon of more than 50 cm thick.
Pellic	having in the upper 30 cm of the soil matrix a Munsell value, moist, of 3.5 or less and a chrome of 1.5 or less (*in Vertisols only*).
Petric	strongly cemented or indurated within 100 cm from the soil surface.
Endopetric	strongly cemented or indurated between 50 and 100 cm from the surface.
Epipetric	strongly cemented or indurated within 50 cm from the soil surface.
Petrocalcic	having a *petrocalcic* horizon within 100 cm from the soil surface.
Petroduric	having a *petroduric* horizon within 100 cm from the soil surface.
Petrogypsic	having a *petrogypsic* horizon within 100 cm from the soil surface.
Petroplinthic	having a *petroplinthic* horizon within 100 cm from the soil surface.
Petrosalic	having within 100 cm from the soil surface a horizon 10 cm or more thick which is cemented by salts more soluble than gypsum.
Placic	having within 100 cm from the soil surface a subhorizon of the *spodic* horizon which is 1 cm or more thick and which is continuously cemented by a combination of organic matter and aluminium, with or without iron ("thin iron pan") (*in Podzols only*).
Plaggic	having a *plaggic* horizon; in *Anthrosols* 50 cm or more thick, in other soils less than 50 cm thick.
Planic	having an eluvial horizon abruptly overlying a slowly permeable horizon within 100 cm from the soil surface.
Plinthic	having a *plinthic* horizon within 100 cm from the soil surface.
Epiplinthic	having a *plinthic* horizon within 50 cm from the soil surface.
Hyperplinthic	having a *plinthic* horizon in which irreversible hardening results in a continuous sheet of ironstone.
Ortihiplinthic	having a *plinthic* horizon in which irreversible hardening results in a layer of gravel-sized ironstone.
Paraplinthic	having a mottled horizon with at least 10 percent (by volume) iron nodules resembling a *plinthic* horizon but which does not irreversibly harden on repeated drying and wetting.
Posic	having a zero or positive charge (pH_{KCl} - pH_{water}) in a layer more than 30 cm thick within 100 cm from the soil surface (*in Ferralsols only*).

Profondic	having an *argic* horizon in which the clay distribution is such that the clay content does not decrease by more than 20 percent (relative) from its maximum within 150 cm from the soil surface.
Protic	showing no appreciable soil horizon development (*in Arenosols only*).
Reductic	having anaerobe conditions caused by gaseous emissions (e.g. methane, carbon dioxide, etc...) (*in Anthropic Regosols only*).
Regic	lacking recognizable buried horizons (*in Anthrosols only*).
Rendzic	having a *mollic* horizon which contains or immediately overlies calcareous materials containing more than 40 percent calcium carbonate equivalent (*in Leptosols only*).
Rheic	having a water regime conditioned by surface water (*in Histosols only*).
Rhodic	having a B horizon which has a Munsell hue redder than 5YR (3.5YR or redder) in all parts (apart from minor transitional horizons to A and C horizons), and has a moist colour value of less than 3.5, and a dry colour value no more than one unit higher than the moist value.
Rubic	having a B horizon (or a horizon immediately below the A horizon) with a dominant Munsell colour hue redder than 10YR and/or a moist chrome of 5 or more (*in Arenosols only*).
Ruptic	having a lithological discontinuity within 100 cm from the soil surface.
Rustic	having a cemented *spodic* horizon which has enough amorphous iron to turn redder on ignition, which underlies an *albic* horizon, and lacks a subhorizon of the *spodic* horizon 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") (*in Podzols only*).
Salic	having a *salic* horizon within 100 cm from the soil surface.
Endosalic	having a *salic* horizon between 50 and 100 cm from the soil surface.
Episalic	having a *salic* horizon between 25 and 50 cm from the soil surface.
Hyposalic	having an electric conductivity of the saturation extract of more than 4 dS m^{-1} at 25°C in at least some subhorizon within 100 cm from the soil surface.
Hypersalic	having an electric conductivity of the saturation extract of more than 30 dS m^{-1} at 25 C in at least some subhorizon within 100 cm of the soil surface.
Sapric	having less than one-sixth (by volume) of the *organic* soil material consisting of recognizable plant tissue (after rubbing) (*in Histosols only*).
Silic	having an *andic* horizon with an acid oxalate (pH 3) extractable silica (Si_{ox}) content of 0.6 percent or more, or an Al_{py}/Al_{ox} ratio of less than 0.5 *in Andosols only*).
Siltic	having 40 percent or more silt in a horizon more than 30 cm thick, within 100 cm from the soil surface.
Skeletic	having between 40 and 90 percent (by weight) gravel or other coarse fragments to a depth of 100 cm from the soil surface.
Endoskeletic	having between 40 and 90 percent (by weight) gravel or other coarse fragments between 50 and 100 cm from the soil surface.

Episkeletic	having between 40 and 90 percent (by weight) gravel or other coarse fragments between 20 and 50 cm from the soil surface.
Sodic	having more than 15 percent exchangeable sodium or more than 50 percent exchangeable sodium plus magnesium on the exchange complex within 50 cm from the soil surface.
Endosodic	having more than 15 percent exchangeable sodium or more than 50 percent exchangeable sodium plus magnesium on the exchange complex between 50 and 100 cm from the soil surface.
Hyposodic	having more than 6 percent saturation with exchangeable sodium in at least some subhorizon more than 20 cm thick within 100 cm from the soil surface.
Spodic	having a *spodic* horizon.
Spolic	having accumulations of *anthropogeomorphic* soil material containing more than 35 percent (by volume) industrial waste (mine soil, river dredgings, highway constructions, etc.) (*in Anthropic Regosols only*).
Stagnic	having *stagnic* properties within 50 cm from the soil surface.
Endostagnic	having *stagnic* properties between 50 and 100 cm from the soil surface.
Sulphatic	having a soil solution (1:1 in water) with $SO_4 >> HCO_3 > Cl$ (*in Solonchaks only*).
Takyric	having a *takyric* horizon.
Tephric	having *tephric* soil material to a depth of 30 cm or more from the soil surface.
Terric	having a *terric* horizon; in *Anthrosols* 50 cm or more thick, in other soils less than 50 cm thick.
Thionic	having a *sulfuric* horizon or *sulfidic* soil material within 100 cm from the soil surface.
Orthithionic	having a *sulfuric* horizon within 100 cm from the soil surface.
Protothionic	having *sulfidic* soil material within 100 cm from the soil surface.
Toxic	having within 50 cm from the soil surface concentrations of ions other than aluminium, iron, sodium, calcium or magnesium which are toxic for plant growth.
Turbic	having cryoturbative features (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), either at the surface or within 100 cm from the soil surface (*in Cryosols only*).
Umbric	having an *umbric* horizon.
Urbic	having accumulations of *anthropogeomorphic* soil material containing more than 35 percent (by volume) earthy materials mixed with building rubble and artifacts (*in Anthropic Regosols only*).
Vermic	having 50 percent or more (by volume) of wormholes, wormcasts, and filled animal burrows in the upper 100 cm of the soil or down to rock or to a *petrocalcic*, *petroduric*, *petrogypsic* or *petroplinthic* horizon, whichever is shallower.
Vertic	having a *vertic* horizon within 100 cm from the soil surface.

Vetic	having less than 6 cmol$_c$ kg^{-1} clay of exchangeable bases plus exchangeable acidity in at least some subhorizon of the B horizon within 100 from the soil surface.
Vitric	having a *vitric* horizon within 100 cm from the soil surface and lacking an andic horizon overlying a vitric horizon.
Xanthic	having a *ferralic* horizon with a yellow to pale yellow colour (rubbed soil has Munsell hues of 7.5YR or yellower with a value, moist, of 4 or more and a chrome, moist, of 5 or more).
Yermic	having a *yermic* horizon including a desert pavement.
Nudiyermic	having a *yermic* horizon without a desert pavement.
The following prefixes may be used to indicate depth of occurrence, or to express the intensity of soil characteristics or properties. They are combined to one word with other elements, e.g. Orthicalci-. A double combination, e.g. Epihypercalci-, is allowed.	
Bathi	horizon, property or material starting between 100 and 200 cm from the soil surface.
Cumuli	having a repetitive accumulation of soil material of 50 cm or more in the surface or A horizon.
Endo	horizon, property or material starting at lower depths, generally between 50 and 100 cm from the soil surface.
Epi	horizon, property or material starting within 50 and 100 cm from the soil surface.
Hyper	having an excessive or strong expression of certain features.
Hypo	having a slight or weak expression of certain features.
Orthi	having a typical expression of certain features (typical in the sense that there is no further or meaningful characterization).
Para	having resemblance to certain features (e.g. Paralithic).
Proto	indicating a precondition or an early stage of development of certain features (e.g. Protothionic).
Thapto	having a buried horizon within 100 cm from the soil surface (given in combination with the buried diagnostic horizon, e.g. Thaptomollic).

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Explanatory notes to the use and definition of a number of lower-level names

Related to diagnostic horizons. Most of the diagnostic horizons can be considered for naming soil subunits with the following exceptions or clarifications.

Argic horizon. The name *Luvic* at the lower level to indicate the occurrence of an argic horizon, rather than Argic. In Arenosols the term **Hypoluvic** is used for the intergrade with Luvisols, although no argic horizon is present.

Cambic horizon. The use of the soil subunit name *Cambic* is in general not recommended.

Ferralic horizon. The name *Ferralic* is not used to indicate the presence of a ferralic horizon, as this would be confusing with the meaning of the diagnostic property and soil unit connotative "ferralic". However, it is used to separate soil subunits having ferralic properties within 100 cm (e.g. **Hypoferralic**).

Sulfuric horizon. The use of the soil subunit name *Sulfuric* is not recommended. Instead of Sulfuri-Thionic, Orthi-Thionic should be used.

Related to diagnostic properties and soil materials. Most of the diagnostic criteria can be used without changing the definition or corresponding connotative of the lower level subdivision. However, the following remarks have to be made.

Colour. Soil colour of the B horizon can be indicated to a varying degree using the terms *Rhodic*, *Rubic*, *Chromic* and *Xanthic*. Preferably these terms should be limited to soils having an argic or ferralic horizon, or applied in Cambisols and Arenosols. In Vertisols the term *Pellic* is used to indicate dark coloured soils.

Dystric/eutric. According to the rules for the definitions of soil subunit names, *Dystric* and *Eutric* have unique meanings, but they should not be used to further specify soils which are clearly acid (e.g. **no** Dystri-Orthithionic Fluvisol) or basic (e.g. **no** Eutri-Petric Calcisol).

Fluvic soil materials. The soil subunit name *Fluvic* may be significant for the reference soil groups of Gleysols and Cambisols, to indicate the presence of fluvic properties. Thin surface mantles of new material (less than 50 cm thick) should be recorded as a phase.

Sodic properties. The soil subunit name *Sodic* can be used indicating an exchangeable sodium percentage (ESP) of more than 15 within 50 cm from the soil surface. An ESP higher than 6 can be indicated by the term **Hyposodic**.

Sulfidic soil materials. The term sulfidic soil materials is used together with the diagnostic sulfuric horizon to separate *Thionic* soil units. If a subdivision of Thionic soil units is required, it is suggested to use the prefix *Proto* for soils with sulfic soil materials only. It is not recommended to use the name Sulfic or Sulfidic to subdivide Thionic soil units.

Tonguing. Provision is made for two types of tonguing: one being tonguing of an albic horizon into a B horizon (**Albiglossic**), the other being the more unusual case of tonguing of an A horizon into the B or C horizon (**Glossic**, **Molliglossic** and **Umbriglossic**).

Priority sequence for the reference soil groups

The priority sequences for the reference soil groups are listed in Table 4. It should be emphasized that the priority sequence for a given reference soil group takes into account the possible connotative combinations for all soil units pertaining to that reference soil group, but not all items in the sequence are necessarily applicable to every individual soil unit defined within the group, because definitions and general rules of the system preclude the occurrence of certain combinations.

TABLE 4: **Priority listing of lower-level units of reference soil groups**

HISTOSOLS	**CRYOSOLS**	**ANTHROSOLS**	**LEPTOSOLS**	**VERTISOLS**
Cryic	Histic	Hydragric	Lithic	Thionic
Glacic	Lithic	Irragric	Gleyic	Salic
Salic	Leptic	Terric	Rendzic	Natric
Gelic	Turbic	Plaggic	Umbric	Gypsic
Thionic	Salic	Hortic	Yermic	Duric
Folic	Natric	Gleyic	Aricic	Calcic
Fibric	Gleyic	Stagnic	Vertic	Alic
Sapric	Andic	Spodic	Gelic	Gypsiric
Ombric	Mollic	Ferralic	Hyperskeletic	Pellic
Rheic	Gypsic	Luvic	Mollic	Grumic
Alcalic	Calcic	Arenic	Humic	Mazic
Toxic	Umbric	Regic	Gypsiric	Chromic
Dystric	Yermic		Calcaric	Mesotrophic
Eutric	Aridic		Dystric	Hyposodic
	Glacic		Eutric	Eutric
	Thionic		Haplic	Haplic
	Oxyaquic			
	Stagnic			
	Haplic			
FLUVISOLS	**SOLONCHAKS**	**GLEYSOLS**	**ANDOSOLS**	**PODZOLS**
Histic	Histic	Histic	Vitric	Gelic
Thionic	Vertic	Thionic	Eutrisilic	Gleyic
Salic	Gleyic	Anthraquic	Silic	Stagnic
Gleyic	Sodic	Endosalic	Gleyic	Densic
Mollic	Mollic	Andic	Melanic	Carbic
Umbric	Gypsic	Vitric	Fulvic	Rustic

Arenic	Duric	Plinthic	Hydric	Histic
Takyric	Calcic	Sodic	Pachic	Umbric
Yermic	Petrosalic	Mollic	Histic	Entic
Aridic	Takyric	Gypsic	Mollic	Placic
Gelic	Yermic	Calcic	Duric	Skeletic
Stagnic	Aridic	Umbric	Umbric	Fragic
Humic	Gelic	Arenic	Luvic	Lamellic
Gypsiric	Stagnic	Takyric	Placic	Anthric
Calcaric	Hypersalic	Gelic	Leptic	Haplic
Sodic	Ochric	Humic	Acroxic	
Tephric	Aceric	Alcalic	Vetic	
Skeletic	Chloridic	Alumic	Calcaric	
Dystric	Sulphatic	Toxic	Arenic	
Eutric	Carbonatic	Abruptic	Sodic	
Haplic	Haplic	Calcaric	Skeletic	
		Tephric	Thaptic	
		Dystric	Dystric	
		Eutric	Eutric	
		Haplic	Haplic	
PLINTHOSOLS	**FERRALSOLS**	**SOLONETZ**	**PLANOSOLS**	**CHERNOZEMS**
Petric	Plinthic	Vertic	Histic	Chernic
Alic	Gleyic	Gleyic	Vertic	Vertic
Acric	Andic	Salic	Thionic	Gleyic
Umbric	Acric	Mollic	Endosalic	Luvic
Albic	Lixic	Gypsic	Plinthic	Glossic
Stagnic	Arenic	Duric	Gleyic	Calcic
Endoeutric	Gibbsic	Calcic	Sodic	Siltic
Geric	Geric	Magnesic	Mollic	Vermic
Humic	Humic	Takyric	Gypsic	Haplic
Endoduric	Histic	Yermic	Calcic	
Vetic	Mollic	Aridic	Alic	
Alumic	Umbric	Stagnic	Luvic	
Abruptic	Endostagnic	Albic	Umbric	
Pachic	Vetic	Humic	Arenic	
Glossic	Posic	Haplic	Gelic	

Ferric	Alumic		Albic	
Haplic	Ferric		Geric	
	Hyperdystric		Petroferric	
	Hypereutric		Alcalic	
	Rhodic		Alumic	
	Xanthic		Ferric	
	Haplic		Calcaric	
			Rhodic	
			Chromic	
			Dystric	
			Eutric	
			Haplic	
KASTANOZEMS	**PHAEOZEMS**	**GYPSISOLS**	**DURISOLS**	**CALCISOLS**
Vertic	Leptic	Petric	Petric	Petric
Gypsic	Vertic	Leptic	Leptic	Leptic
Calcic	Gleyic	Vertic	Vertic	Vertic
Luvic	Andic	Endosalic	Gypsic	Endosalic
Hyposodic	Vitric	Sodic	Calcic	Gleyic
Siltic	Sodic	Duric	Luvic	Sodic
Chromic	Luvic	Calcic	Arenic	Luvic
Anthric	Albic	Luvic	Takyric	Takyric
Haplic	Stagnic	Takyric	Yermic	Yermic
	Greyic	Yermic	Aridic	Aridic
	Pachic	Aridic	Chromic	Skeletic
	Abruptic	Arzic	Hyperochric	Hyperochric
	Glossic	Skeletic	Haplic	Hypercalcic
	Tephric	Hyperochric		Hypocalcic
	Calcaric	Hypergypsic		Haplic
	Skeletic	Hypogyspic		
	Siltic	Haplic		
	Vermic			
	Chromic			
	Haplic			
ALBELUVISOLS	**ALISOLS**	**NITISOLS**	**ACRISOLS**	**LUVISOLS**
Histic	Vertic	Andic	Leptic	Leptic

Gelic	Plinthic	Mollic	Plinthic	Vertic
Gleyic	Gleyic	Alic	Gleyic	Gleyic
Alic	Andic	Umbric	Andic	Andic
Umbric	Nitic	Humic	Vitric	Vitric
Arenic	Umbric	Vetic	Umbric	Calcic
Fragic	Arenic	Alumic	Arenic	Arenic
Stagnic	Stagnic	Rhodic	Stagnic	Stagnic
Alumic	Albic	Ferralic	Geric	Albic
Endoeutric	Humic	Dystric	Albic	Hyposodic
Abruptic	Abruptic	Eutric	Humic	Profondic
Ferric	Profondic	Haplic	Vetic	Lamellic
Siltic	Lamellic		Abruptic	Ferric
Haplic	Ferric		Profondic	Rhodic
	Hyperdystric		Lamellic	Chromic
	Skeletic		Ferric	Cutanic
	Rhodic		Alumic	Hyperochric
	Chromic		Hyperdystric	Dystric
	Haplic		Skeletic	Haplic
			Rhodic	
			Chromic	
			Hyperochric	
			Haplic	
LIXISOLS	**UMBRISOLS**	**CAMBISOLS**	**ARENOSOLS**	**REGOSOLS**
Leptic	Gelic	Gelic	Gelic	Gelic
Plinthic	Leptic	Leptic	Plinthic	Leptic
Gleyic	Gleyic	Vertic	Gleyic	Gleyic
Andic	Arenic	Fluvic	Hypoluvic	Thaptoandic
Vitric	Stagnic	Endosalic	Yermic	Thaptovitric
Calcic	Albic	Plinthic	Aridic	Arenic
Arenic	Humic	Gelistagnic	Ferralic	Takyric
Stagnic	Ferralic	Stagnic	Albic	Yermic
Geric	Skeletic	Gleyic	Gypsiric	Aridic
Albic	Anthric	Andic	Calcaric	Gelistagnic
Humic	Haplic	Vitric	Lamellic	Stagnic
Vetic		Mollic	Rubic	Anthropic

Abruptic		Takyric	Fragic	Aric
Profondic		Yermic	Hyposalic	Garbic
Lamellic		Aridic	Tephric	Reductic
Ferric		Sodic	Hypoduric	Spolic
Rhodic		Ferralic	Protic	Urbic
Chromic		Gypsiric	Dystric	Humic
Hyperochric		Calcaric	Eutric	Vermic
Haplic		Skeletic	Haplic	Hyposalic
		Rhodic		Hyposodic
		Chromic		Gypsiric
		Hyperochric		Calcaric
		Dystric		Tephric
		Eutric		Skeletic
		Haplic		Hyperochric
				Dystric
				Eutric
				Haplic

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Appendix 1: Soil horizon designations

MASTER HORIZONS AND LAYERS

The capital letters **H. O. A, E, B. C** and **R** represent the master horizons and layers of soils. The capital letters are the base symbols to which other characters are added to complete the designation. Most horizons and layers are given a single capital letter symbol, but some require two. Currently seven master horizons and layers are recognized.

The master horizons and their subdivisions represent layers which show evidence of change and some layers which have not been changed. Most are genetic soil horizons, reflecting a qualitative judgement about the kind of changes which have taken place. Genetic horizons are not equivalent to diagnostic horizons, although they may be identical in soil profiles. Diagnostic horizons are quantitatively defined features used in classification.

H horizons or layers: Layers dominated by organic material, formed from accumulations of undecomposed or partially decomposed organic material at the soil surface which may be underwater. All **H** horizons are saturated with water for prolonged periods or were once saturated but are now artificially drained. An **H** horizon may be on top of mineral soils or at any depth beneath the surface if it is buried.

O horizons or layers: Layers dominated by organic material, consisting of undecomposed or partially decomposed litter, such as leaves, needles, twigs, moss, and lichens, which has accumulated on the surface; they may be on top of either mineral or organic soils. **O** horizons are not saturated with water for prolonged periods. The mineral fraction of such material is only a small percentage of the volume of the material and generally is much less than half of the weight.

An **O** layer may be at the surface of a mineral soil or at any depth beneath the surface if it is buried. An horizon formed by illuviation of organic material into a mineral subsoil is not an **O** horizon, though some horizons formed in this manner contain much organic matter.

A horizons: Mineral horizons which formed at the surface or below an **O** horizon, in which all or much of the original rock structure has been obliterated and which are characterized by one or more of the following:

- an accumulation of humified organic matter intimately mixed with the mineral fraction and not displaying properties characteristic of **E** or **B** horizons (see below);

- properties resulting from cultivation, pasturing, or similar kinds of disturbance; or

- a morphology which is different from the underlying **B** or **C** horizon, resulting from processes related to the surface.

If a surface horizon has properties of both **A** and **E** horizons but the dominant feature is an accumulation of humified organic matter, it is designated an **A** horizon. In some places, such as warm arid climates, the undisturbed surface horizon is less dark than the adjacent underlying horizon and contains only small amounts of organic matter. It has a morphology distinct from the **C** layer, though the mineral fraction may be unaltered or only slightly altered by weathering. Such an horizon is designated A because it is at the surface. Examples of soils which may have a different structure or morphology due to surface processes are Vertisols, soils in pans or playas with little vegetation, and soils in deserts. However, recent alluvial or aeolian deposits that retain fine stratification are not considered to be an **A** horizon unless cultivated.

E horizons: Mineral horizons in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these, leaving a concentration of sand and silt particles, and in which all or much of the original rock structure has been obliterated.

An **E** horizon is usually, but not necessarily, lighter in colour than an underlying **B** horizon. In some soils the colour is that of the sand and silt particles, but in many soils coatings of iron oxides or other compounds mask the colour of the primary particles. An **E** horizon is most commonly differentiated from an underlying **B** horizon in the same soil profile by colour of a higher value or lower chrome, or both; by coarser texture; or by a combination of these properties. An **E** horizon is commonly near the surface, below an **O** or **A** horizon and above a **B** horizon, but the symbol **E** may be used without regard to position in the profile for any horizon that meets the requirements and that has resulted from soil genesis.

B horizons: Horizons that formed below an **A**, **E**, **O or H** horizon, and in which the dominant features are the obliteration of all or much of the original rock structure, together with one or a combination of the following:

- illuvial concentration, alone or in combination, of silicate clay, iron, aluminum, humus, carbonates, gypsum or silica;

- evidence of removal of carbonates;

- residual concentration of sesquioxides;

- coatings of sesquioxides that make the horizon conspicuously lower in value, higher in chrome, or redder in hue than overlying and underlying horizons without apparent illuviation of iron;

- alteration that forms silicate clay or liberates oxides or both and that forms a granular, blocky, or prismatic structure if volume changes accompany changes in moisture content; or

- brittleness.

All kinds of **B** horizons are, or were originally, subsurface horizons. Included as **B** horizons are layers of illuvial concentration of carbonates, gypsum, or silica that are the result of pedogenetic processes (these layers may or may not be cemented) and brittle layers that have other evidence of alteration, such as prismatic structure or illuvial accumulation of clay.

Examples of layers that are not **B** horizons are layers in which clay films either coat rock fragments or are on finely stratified unconsolidated sediments, whether the films were formed in place or by illuviation; layers into which carbonates have been illuviated but that are not contiguous to an overlying genetic horizon; and layers with gleying but no other pedogenetic changes.

C horizons or layers: Horizons or layers, excluding hard bedrock, that are little affected by pedogenetic processes and lack properties of **H. O. A, E**, or **B** horizons. Most are mineral layers, but some siliceous and calcareous layers such as shells, coral and diatomaceous earth, are included. The material of **C** layers may be either like or unlike that from which the solum presumably formed. A **C** horizon may have been modified even if there is no evidence of pedogenesis. Plant roots can penetrate **C** horizons, which provide an important growing medium.

Included as **C** layers are sediments, saprolite, and unconsolidated bedrock and other geologic materials that commonly slake within 24 hours when air dry or drier chunks are placed in water and when moist can be dug with a spade. Some soils form in material that is already highly weathered, and such material that does not meet the requirements of **A, E** or **B** horizons is designated **C**. Changes not considered pedogenetic are those not related to overlying horizons. Layers having accumulations of silica, carbonates, or gypsum, even if indurated, may be included in **C** horizons, unless the layer is obviously affected by pedogenetic processes; then it is a **B** horizon.

R layers: Hard bedrock underlying the soil.

Granite, basalt, quartzite and indurated limestone or sandstone are examples of bedrock that are designated **R**. Air dry or drier chunks of an **R** layer when placed in water will not slake within 24 hours. The **R** layer is sufficiently coherent when moist to make hand digging with a spade impractical, although it may be chipped or scraped. Some **R** layers can be ripped with heavy power equipment. The bedrock may contain cracks, but these are so few and so small that few roots can penetrate. The cracks may be coated or filled with clay or other material.

Appendix 2: Codes for the reference soil groups and soil subunits

A. Reference Soil Group Codes

AC	Acrisol
AB	Albeluvisol
AL	Alisol
AN	Andosol
AT	Anthrosol
AR	Arenosol
CL	Calcisol
CM	Cambisol
CH	Chernozem
CR	Cryosol
DU	Durisol
FR	Ferralsol
FL	Fluvisol
GL	Gleysol
GY	Gypsisol
HS	Histosol
KS	Kastanozem
LP	Leptosol
LX	Lixisol
LV	Luvisol
NT	Nitisol
PH	Phaeozem
PL	Planosol
PT	Plinthosol
PZ	Podzol
RG	Regosol
SC	Solonchak
SN	Solonetz

UM	Umbrisol
VR	Vertisol

B. Soil Unit Adjectives Codes

ap	Abruptic	
ae	Aceric	
ac	Acric	
ao	Acroxic	
ab	Albic	
	abh	Hyperalbic
	abg	Glossalbic
ax	Alcalic	
al	Alic	
au	Alumic	
an	Andic	
	ana	Aluandic
	ans	Silandic
aq	Anthraquic	
am	Anthric	
ah	Anthropic	
ai	Aric	
ar	Arenic	
ad	Aridic	
az	Arzic	
ca	Calcaric	
cc	Calcic	
	cch	Hypercalcic
	ccw	Hypocalcic
	cco	Orthicalcic
cb	Carbic	
cn	Carbonatic	
ch	Chernic	
cl	Chloridic	
cr	Chromic	

cy	Cryic	
ct	Cutanic	
dn	Densic	
du	Duric	
dy	Dystric	
	dye	Epidystric
	dyh	Hyperdystric
	dyo	Orthidystric
et	Entic	
eu	Eutric	
	eun	Endoeutric
	euh	Hypereutric
	euo	Orthieutric
es	Eutrisilic	
fl	Ferralic	
	flh	Hyperferralic
	flw	Hypoferralic
fr	Ferric	
	frh	Hyperferric
fi	Fibric	
fo	Folic	
fv	Fluvic	
fg	Fragic	
fu	Fulvic	
ga	Garbic	
ge	Gelic	
gt	Gelistagnic	
gr	Geric	
gi	Gibbsic	
gc	Glacic	
gl	Gleyic	

	gln	Endogleyic
	glp	Epigleyic
gs	Glossic	
	gsm	Molliglossic
	gsu	Umbriglossic
gz	Greyic	
gm	Grumic	
gy	Gypsic	
	gyh	Hypergypsic
	gyw	Hypogypsic
gp	Gypsiric	
ha	Haplic	
hi	Histic	
	hif	Fibrihistic
	his	Saprihistic
	hib	Thaptohistic
ht	Hortic	
hu	Humic	
	hum	Mollihumic
	huu	Umbrihumic
hg	Hydragric	
hy	Hydric	
hk	Hyperskeletic	
ir	Irragric	
II	Lamellic	
le	Leptic	
	len	Endoleptic
	lep	Epileptic
li	Lithic	
	lip	Paralithic
Ix	Lixic	
Iv	Luvic	

	lvw	Hypoluvic
mg	Magnesic	
mz	Mazic	
me	Melanic	
ms	Mesotrophic	
mo	Mollic	
na	Natric	
ni	Nitic	
oh	Ochric	
	ohh	Hyperochric
om	Ombric	
or	Orthic	
oa	Oxyaquic	
ph	Pachic	
pe	Pellic	
pt	Petric	
	ptp	Epipetric
pc	Petrocalcic	
pd	Petroduric	
pg	Petrogypsic	
pp	Petroplinthic	
ps	Petrosalic	
pi	Placic	
pa	Plaggic	
pn	Planic	
pl	Plinthic	
	plp	Epiplinthic
	plh	Hyperplinthic
	plo	Orthiplinthic
	plr	Paraplinthic
po	Posic	
pf	Profondic	

pr	Protic	
rd	Reductic	
rg	Regic	
rz	Rendzic	
rh	Rheic	
ro	Rhodic	
ru	Rubic	
rp	Ruptic	
rs	Rustic	
sz	Salic	
	szn	Endosalic
	szp	Episalic
	szw	Hyposalic
sa	Sapric	
si	Silic	
sl	Siltic	
sk	Skeletic	
	skn	Endoskeletic
	skp	Episkeletic
so	Sodic	
	son	Endosodic
	sow	Hyposodic
sd	Spodic	
sp	Spolic	
st	Stagnic	
	stn	Endostagnic
su	Sulphatic	
ty	Takyric	
tf	Tephric	
tr	Terric	
ti	Thionic	
	tio	Orthithionic

	tit	Protothionic
tx	Toxic	
tu	Turbic	
um	Umbric	
ub	Urbic	
vt	Vetic	
vm	Vermic	
vr	Vertic	
vi	Vitric	
xa	Xanthic	
ye	Yermic	
	yes	Nudiyermic

Soil Unit Specifier Codes

d	Bathi
c	Cumuli
n	Endo
p	Epi
h	Hyper
w	Hypo
o	Orthi
r	Para
t	Proto
b	Thapto

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** Out of print

This publication is a technical manual for soil scientists and soil correlators, designed to facilitate the exchange of information and experience to provide a common scientific language to enhance communication with other disciplines. It contains definitions and diagnostic criteria for soil horizons, soil properties and soil materials and gives rules and guidelines for classifying and subdividing soil reference groups.

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