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World reference base for soil resources 2014

International soil classification system for naming soils and creating legends for soil maps

Update 2015

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International soil classification system for naming soils and creating legends for soil maps

Update 2015

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Foreword

The first edition of the World Reference Base for Soil Resources (WRB) was released at the 16th World Congress of Soil Science at Montpellier in 1998. At the same event, it was also endorsed and adopted as the system for soil correlation and international communication of the International Union of Soil Sciences (IUSS). The second edition of the WRB was released at the 18th World Congress at Philadelphia in 2006.

After an additional eight years of intensive worldwide testing and data collection, the third edition of the WRB is presented. This publication builds on and reflects the valuable work of the authors of the earlier drafts and editions of the WRB, as well as the experiences and contributions of many soil scientists who participated in the work of the IUSS Working Group on the WRB.

The WRB is a soil classification system for naming soils and creating soil map legends. It is hoped that this publication will contribute to the understanding of soil science in the general public and in the scientific community.

The publication has been made possible by the sustained efforts of a large group of expert authors, as well as the cooperation and logistic support of the IUSS and the Food and Agriculture Organization of the United Nations (FAO).

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The fundamental decisions have been made by the members of the WRB Board: Lúcia Anjos (Brazil), Carlos Cruz Gaistardo (Mexico), Seppe Deckers (Belgium), Stefaan Dondeyne (Belgium), Einar Eberhardt (Germany), Maria Gerasimova (Russia), Ben Harms (Australia), Arwyn Jones (European Commission), Pavel Krasilnikov (Russia), Thomas Reinsch (United States of America), Ronald Vargas (FAO), and Ganlin Zhang (China). Language editing was performed by Ben Harms (Australia).

The current third edition received contributions from many scientists, among them are: David Badia Villas (Spain), Frank Berding (The Netherlands), Hans-Peter Blume (Germany), Vanda Buivydaite (Lithuania), Wolfgang Burghardt (Germany), Przemysław Charzynski (Poland), Joe Chiaretti (United States of America), Juan Comerma (Venezuela), Carmelo Dazzi (Italy), Mahmut Dingil (Turkey), Arnulfo Encina Rojas (Paraguay), Márta Fuchs (Hungary), Luise Giani (Germany), Sergey Goryachkin (Russia), Alfred Hartemink (United States of America), Juan José Ibañez Martí (Spain), Plamen Ivanov (Bulgaria), Reinhold Jahn (Germany), Jerôme Juilleret (Luxembourg), Cezary Kabała (Poland), Andrzej Kacprzak (Poland), Arno Kanal (Estonia), Nikolay Khitrov (Russia), Roger Langohr (Belgium), Xavier Legrain (Belgium), Andreas Lehmann (Germany), Peter Lüscher (Switzerland), Gerhard Milbert (Germany), Brian Murphy (Australia), Freddy Nachtergaele (FAO), Otmar Nestroy (Austria), Åge Nyborg (Norway), Tatiana Prokofieva (Russia), David Rossiter (The Netherlands), Daniela Sauer (Germany), Jaroslava Sobocká (Slovakia), Karl Stahr (Germany), Leigh Sullivan (Australia), Wenceslau Teixeira (Brazil), Łukasz Uzarowicz (Poland).

The Working Group is greatly indebted to two brilliant soil scientists who made tremendous contributions to the development of the WRB and have sadly passed away: Rudi Dudal (Belgium, 1926–2014) was the lead author of the Soil Map of the World, and Otto Spaargaren (The Netherlands, 1944–2015) was for a long time the leading scientist of the WRB Working Group.

Finally, the Working Group wishes to express its gratitude to the FAO for its support and for making possible the printing and distribution of this publication.

List of acronyms

Al_{dith}	Aluminium extracted by a dithionite-citrate-bicarbonate solution
Al_{ox}	Aluminium extracted by an acid ammonium oxalate solution
Al_{py}	Aluminium extracted by a pyrophosphate solution
$CaCO_3$	Calcium carbonate
CEC	Cation exchange capacity
COLE	Coefficient of linear extensibility
EC	Electrical conductivity
EC_e	Electrical conductivity of saturation extract
ESP	Exchangeable sodium percentage
FAO	Food and Agriculture Organization of the United Nations
Fe_{dith}	Iron extracted by a dithionite-citrate-bicarbonate solution
Fe_{ox}	Iron extracted by an acid ammonium oxalate solution
Fe_{py}	Iron extracted by a pyrophosphate solution
HCl	Hydrochloric acid
ISRIC	International Soil Reference and Information Centre
ISSS	International Society of Soil Science
IUSS	International Union of Soil Sciences
KOH	Potassium hydroxide
KCl	Potassium chloride
Mn_{dith}	Manganese extracted by a dithionite-citrate-bicarbonate solution
NaOH	Sodium hydroxide
NH_4OAc	Ammonium acetate
ODOE	Optical density of the oxalate extract
RSG	Reference Soil Group

SAR	Sodium adsorption ratio
Si_{ox}	Silicon extracted by an acid ammonium oxalate solution
SiO_2	Silica
SUITMA	Soils in Urban, Industrial, Traffic, Mining and Military Areas (IUSS working group)
TRB	Total reserve of bases
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USDA	United States Department of Agriculture
WRB	World Reference Base for Soil Resources

Chapter 1
Background and basics

1.1 HISTORY

From its beginnings to the second edition 2006

The World Reference Base (WRB) is based on the Legend (FAO-Unesco, 1974) and the Revised Legend (FAO, 1988) of the Soil Map of the World (FAO-Unesco, 1971-1981). In 1980, the International Society of Soil Science (ISSS, since 2002 the International Union of Soil Sciences, IUSS) formed a Working Group 'International Reference Base for Soil Classification' for further elaboration of a science based international soil classification system. This Working Group was renamed 'World Reference Base for Soil Resources' in 1992. The Working Group presented the first edition of the WRB in 1998 (FAO, 1998) and the second edition in 2006 (IUSS Working Group WRB, 2006). In 1998, the ISSS Council endorsed the WRB as its officially recommended terminology to name and classify soils.

A detailed description of the WRB history before 2006 is given in the second edition of the WRB (IUSS Working Group WRB, 2006).

From the second edition 2006 to the third edition 2014

The second edition of the WRB was presented at the 18th World Congress of Soil Science 2006 in Philadelphia, USA (book: IUSS Working Group WRB, 2006; file: ftp://ftp.fao.org/agl/agll/docs/wsrr103e.pdf. After publication, some errors and needs for improvement were identified, and an electronic update was published in 2007 http://www.fao.org/fileadmin/templates/nr/images/resources/pdf_documents/wrb2007_red.pdf.

The second edition was translated into several languages. The Russian translation is of the 2006 printed version; whereas all other translations are of the 2007 electronic update: Arabic, German, Polish, Slovak, Spanish, and Turkish.

Since 2006, several WRB field correlation tours were organized to test the second edition:

2007: Germany (special topic: Technosols and Stagnosols)

2009: Mexico

2010: Norway

2011: Poland

2012: Australia (Victoria and Tasmania)

2013: Russia (ultra-continental permafrost soils in Sakha)

The field tours associated with the meetings of the IUSS Commission on Soil Classification in Chile (2008) and the United States (Nebraska and Iowa, 2012) were additional tests of the second edition and also the tours offered with the 19th World Congress of Soil Science 2010 in Australia.

The second edition of the WRB is a system to classify soils. Soon after its publication, there was an identified demand to create map legends using the WRB. For this purpose, the 'Guidelines for constructing small-scale map legends using the WRB' were published in 2010 http://www.fao.org/nr/land/soils/soil/wrb-documents/en/. They were recommended for map scales of 1 : 250 000 or smaller. The version for classifying soils (2006/07) and the version for creating map legends (2010) are based on the same definitions, but use different qualifier sequences and different rules for using the qualifiers (see below).

Now, after 8 years, a third edition has been prepared.

1.2 MAJOR CHANGES IN WRB 2014

The major changes are:

- The qualifier sequences and the rules for qualifier usage are now suitable for both classifying soils and creating map legends. They are now subdivided into principal qualifiers (ranked for every Reference Soil Group, RSG, in order of relevance) and supplementary qualifiers (not ranked).

- The only change at the Reference Soil Group (RSG) level is to replace Albeluvisols by Retisols. Retisols have a broader definition and include the former Albeluvisols.

- Fluvisols have moved down in the key to be the second last RSG. The Umbrisols are now placed directly after Phaeozems. The following RSGs switched their positions: Solonetz and Vertisols, Durisols and Gypsisols, Cambisols and Arenosols. The soils characterized by an argic horizon now have the following order: Acrisols – Lixisols – Alisols – Luvisols.

- The definition of Gleysols has been broadened.

- The definition of Acrisols, Alisols, Luvisols and Lixisols has been narrowed by setting the lower depth limit for the occurrence of the argic horizon uniformly to 100 cm. This implicitly widens the definition of Arenosols.

- There are now two different types of base saturation in use. First, the effective base saturation is used to separate Acrisols from Lixisols, Alisols from Luvisols and the Dystric qualifier from the Eutric qualifier. It is defined in WRB as exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered). Second, the base saturation (pH 7) is used for all other purposes. It is defined in WRB as exchangeable(Ca + Mg + K + Na) / CEC (pH 7); CEC and exchangeable bases by 1 M NH_4OAc (pH 7).

- Three new diagnostic horizons have been defined. The chernic horizon replaces the voronic horizon and is required for Chernozems. The pretic horizon allows a better accommodation of 'Terra preta de Indio' within the Anthrosols. The protovertic horizon (the former vertic properties) describes layers with weakly expressed shrink-swell features.

- The anthric, takyric and yermic horizons have been changed to diagnostic properties.

- 'Retic properties' are a newly introduced diagnostic property in order to characterize Retisols. 'Albeluvic glossae' replaces 'albeluvic tonguing'. 'Shrink-swell cracks' are a new diagnostic property that is useful for the definition of Vertisols and related soils.

- Some new names have been created: 'protocalcic properties' (instead of 'secondary carbonates'), 'sideralic properties' (instead of 'ferralic properties'). The 'gleyic colour pattern' and the 'stagnic colour pattern' are now 'gleyic properties' and 'stagnic properties' repectively. The 'abrupt textural change' has been renamed 'abrupt textural difference'; and 'lithological discontinuity' is now 'lithic discontinuity'.

- The albic horizon has been redefined as 'albic material'.

- 'Soil organic carbon' has been introduced to separate pedogenetic organic carbon from organic carbon that satisfies the diagnostic criteria of artefacts. 'Dolomitic material' is a new diagnostic material. 'Hypersulfidic material' and 'hyposulfidic material' are introduced as specific varieties of sulfidic material.

- 'Technic hard rock' has been renamed 'technic hard material'.

- Major improvements have been made in the definitions of the argic and natric horizons, in the depth criteria of the mollic and umbric horizons and in the separation between organic and mineral materials.

- Several new qualifiers have been added to give more information about some important soil properties. Precise rules have been introduced for the use of specifiers to define subqualifiers.

- The WRB should be able to express characteristics regarded as important in national systems. Some amendments have been made to allow for the better representation of soil units in the WRB, for example from the Australian and the Brazilian systems.

- Some parts of the world had not previously been well represented in the WRB system before, e.g. ultra-continental permafrost soils. The system has been enlarged to allow a better classification of these soils.

- Efforts have been made to improve the clarity of definitions and terminology.

1.3 THE OBJECT CLASSIFIED IN THE WRB

Like many common words, 'soil' has several meanings. In its traditional meaning, soil is the natural medium for the growth of plants, whether or not it has discernible soil horizons (Soil Survey Staff, 1999).

In the 1998 WRB, soil was defined as:

"… a continuous natural body which has three spatial and one temporal dimension. The three main features governing soil 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 structures of the soil cover facilitates perception of the physical, chemical and biological properties; it permits understanding the past and present of the soil, and predicting its future.*

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

Although there are good arguments to limit soil survey and mapping to identifiable stable soil areas with a certain thickness, the WRB has taken the more comprehensive approach to name any object forming part of the ***epiderm of the earth*** (Sokolov, 1997; Nachtergaele, 2005). This approach has a number of advantages; notably that it allows for the tackling environmental problems in a systematic and holistic way, and avoids sterile discussion on a universally agreed definition of soil and its required thickness and stability. Therefore, the object classified in the WRB is: *any material within 2 m of the Earth's surface that is in contact with the atmosphere, excluding living organisms, areas with continuous ice not covered by other material, and water bodies deeper than* 2 m[1]. If explicitly stated, the object classified in the WRB includes layers deeper than 2 m.

The definition includes continuous rock, paved urban soils, soils of industrial areas, cave soils as well as subaqueous soils. Soils under continuous rock, except those that occur in caves, are generally not considered for classification. In special cases, the WRB may be used to classify soils under rock, for example for palaeopedological reconstruction of the environment.

1.4 BASIC PRINCIPLES

General principles

- The classification of soils is based on soil properties defined in terms of diagnostic horizons, diagnostic properties and diagnostic materials, which to the greatest extent possible should be measurable and observable in the field. Table 1 provides an overview of the diagnostics uned in the WRB.

- The selection of diagnostic characteristics takes into account their relationship with soil forming processes. An understanding of soil-forming processes contributes to a better characterization of soils but these processes should not, as such, be used as differentiating criteria.

- To the extent possible at a high level of generalization, diagnostic features that are of significance for soil management are selected.

[1] In tidal areas, the depth of 2 m is to be applied at mean low water springs.

- Climate parameters are not applied in the classification of soils. It is understood that they should be used for interpretation purposes, in combination with soil properties, but they should not form part of soil definitions. The classification of soils is therefore not subordinated to the availability of climate data. The name of a certain soil will not become obsolete due to global or local climate change.

- The WRB is a comprehensive classification system that enables accommodation of national soil classification systems.

- The WRB is not intended to be a substitute for national soil classification systems, but rather to serve as a common denominator for communication at the international level.

- The WRB comprises two levels of categorical detail:

  - the ***First Level*** having 32 Reference Soil Groups (RSGs);

  - the ***Second Level***, consisting of the name of the RSG combined with a set of principal and supplementary qualifiers.

- Many RSGs in the WRB are representative of major soil regions so as to provide a comprehensive overview of the world's soil cover.

- Definitions and descriptions reflect variations in soil characteristics that occur both vertically and laterally in the landscape.

- The term *Reference Base* is connotative of the common denominator function of the WRB: its units (RSGs) have sufficient width to facilitate harmonization and correlation with existing national systems.

- In addition to serving as a correlation between existing classification systems, the WRB also serves as a 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 retains terms that have been used traditionally or that can be introduced easily into current language. They are defined precisely, in order to avoid the confusion that occurs where names are used with different connotations.

TABLE 1
The diagnostic horizons, properties and materials of the WRB

Note -– this table does not provide definitions. For diagnostic criteria, please refer to Chapter 3.

Name	Simplified Description
1. Anthropogenic diagnostic horizons (all are mineral)	
anthraquic horizon	in paddy soils: the layer comprising the puddled layer and the plough pan, both showing a reduced matrix and oxidized root channels
hortic horizon	dark, high content of organic matter and P, high animal activity, high base saturation; resulting from long-term cultivation, fertilization and application of organic residues
hydragric horizon	in paddy soils: the layer below the anthraquic horizon showing redoximorphic features and/or an accumulation of Fe and/or Mn

irragric horizon	uniformly structured, at least moderate content of organic matter, high animal activity; gradually built up by sediment-rich irrigation water
plaggic horizon	dark, at least moderate content of organic matter, sandy or loamy; resulting from application of sods and excrements
pretic horizon	dark, high content of organic matter and P, low animal activity, high contents of exchangeable Ca and Mg, with remnants of charcoal and/or artefacts; including Amazonian Dark Earths
terric horizon	showing a colour related the source material, high base saturation; resulting from adding mineral material (with or without organic residues) and deep cultivation

2. Diagnostic horizons that may be organic or mineral

cryic horizon	perennially frozen (visible ice or, if not enough water, ≤ 0°C)
calcic horizon	accumulation of secondary carbonates, non-cemented
fulvic horizon	andic properties, highly humified organic matter, higher ratio of fulvic acids to humic acids
melanic horizon	andic properties, highly humified organic matter, lower ratio of fulvic acids to humic acids, blackish
salic horizon	high amounts of readily soluble salts
thionic horizon	with sulfuric acid and a very low pH

3. Organic diagnostic horizons

folic horizon	organic layer, not water-saturated and not drained
histic horizon	organic layer, water-saturated or drained

4. Surface mineral diagnostic horizons

chernic horizon	thick, very dark-coloured, high base saturation, moderate to high content of organic matter, well-structured, high biological activity (special case of the mollic horizon)
mollic horizon	thick, dark-coloured, high base saturation, moderate to high content of organic matter, not massive and hard when dry
umbric horizon	thick, dark-coloured, low base saturation, moderate to high content of organic matter, not massive and hard when dry

5. Other mineral diagnostic horizons related to the accumulation of substances due to (vertical or lateral) migration processes

argic horizon	subsurface layer with distinctly higher clay content than the overlying layer and/or presence of illuvial clay
duric horizon	concretions or nodules, cemented or indurated by silica
ferric horizon	≥ 5% reddish to blackish concretions and/or nodules or ≥ 15% reddish to blackish coarse mottles, with accumulation of Fe (and Mn) oxides
gypsic horizon	accumulation of secondary gypsum, non-cemented
natric horizon	subsurface layer with distinctly higher clay content than the overlying layer and/or presence of illuvial clay; high content of exchangeable Na
petrocalcic horizon	accumulation of secondary carbonates, relatively continuously cemented or indurated
petroduric horizon	accumulation of secondary silica, relatively continuously cemented or indurated
petrogypsic horizon	accumulation of secondary gypsum, relatively continuously cemented or indurated
petroplinthic horizon	sheet of connected yellowish, reddish and/or blackish concretions and/or nodules or of concentrations in platy, polygonal or reticulate patterns; high contents of Fe oxides at least in the concretions, nodules or concentrations; relatively continuously cemented or indurated
pisoplinthic horizon	≥ 40% strongly cemented to indurated, yellowish, reddish, and/or blackish concretions and/or nodules, with accumulation of Fe oxides

plinthic horizon	≥ 15% (single or in combination) of reddish concretions and/or nodules or of concentrations in platy, polygonal or reticulate patterns; high contents of Fe oxides, at least in the concretions, nodules or concentrations
sombric horizon	subsurface accumulation of organic matter other than in spodic or natric horizons
spodic horizon	subsurface accumulation of organic matter and/or Fe and Al
6. Other mineral diagnostic horizons	
cambic horizon	evidence of pedogenic alteration; not meeting the criteria of diagnostic horizons that indicate stronger alteration or accumulation processes
ferralic horizon	strongly weathered; dominated by kaolinites and oxides
fragic horizon	structure compact to the extent that roots and percolating water penetrate only along interped faces; non-cemented
nitic horizon	rich in clay and Fe oxides, moderate to strong structure, shiny aggregate faces
protovertic horizon	influenced by swelling and shrinking clays
vertic horizon	dominated by swelling and shrinking clays
7. Diagnostic properties related to surface characteristics	
aridic properties	surface layer characteristics of soils under arid conditions
takyric properties	heavy-textured surface layers under arid conditions in periodically flooded soils (special case of aridic properties)
yermic properties	pavement and/or vesicular layer in soils under arid conditions (special case of aridic properties)
8. Diagnostic properties defining the relationship between two layers	
abrupt textural difference	very sharp increase in clay content within a limited depth range
albeluvic glossae	interfingering of coarser-textured and lighter coloured material into an argic horizon forming vertically continuous tongues (special case of retic properties)
lithic discontinuity	differences in parent material
retic properties	interfingering of coarser-textured and lighter coloured material into an argic or natric horizon
9. Other diagnostic properties	
andic properties	short-range-order minerals and/or organo-metallic complexes
anthric properties	applying to soils with mollic or umbric horizons, if the mollic or umbric horizon is created or substantially transformed by humans
continuous rock	consolidated material (excluding cemented or indurated pedogenetic horizons)
geric properties	very low effective CEC and/or acting as anion exchanger
gleyic properties	saturated with groundwater (or upwards moving gases) long enough that reducing conditions occur
protocalcic properties	carbonates derived from the soil solution and precipitated in the soil (secondary carbonates), less pronounced than in calcic or petrocalcic horizons
reducing conditions	low rH value and/or presence of sulfide, methane or reduced Fe
shrink-swell cracks	open and close due to swelling and shrinking of clay minerals
sideralic properties	relatively low CEC
stagnic properties	saturated with surface water (or intruding liquids), at least temporarily, long enough that reducing conditions occur

vitric properties	≥ 5% (by grain count) of volcanic glass and related materials and containing a limited amount of short-range-order minerals and/or organo-metallic complexes
10. Diagnostic materials related to the concentration of organic carbon	
mineral material	< 20% soil organic carbon
organic material	≥ 20% soil organic carbon
soil organic carbon	organic carbon that does not meet the diagnostic criteria of artefacts
11. Diagnostic material related to colour	
albic material	light-coloured fine earth, expressed by high Munsell value and low chroma
12. Technogenic diagnostic materials (predominantly understood as parent materials)	
artefacts	created, substantially modified or brought to the surface by humans; no subsequent substantial change of chemical or mineralogical properties
technic hard material	consolidated and relatively continuous material resulting from an industrial process
13. Other diagnostic materials (predominantly understood as parent materials)	
calcaric material	≥ 2% calcium carbonate equivalent, inherited from the parent material
colluvic material	heterogeneous mixture that has moved down a slope
dolomitic material	≥ 2% of a mineral that has a ratio CaCO3/MgCO3 < 1.5
fluvic material	fluviatile, marine or lacustrine deposits with evident stratification
gypsiric material	≥ 5% gypsum, at least partially inherited from the parent material
hypersulfidic material	sulfidic material capable of severe acidification
hyposulfidic material	sulfidic material not capable of severe acidification
limnic material	deposited in water by precipitation or through action of aquatic organisms
ornithogenic material	remnants of birds or bird activity
sulfidic material	containing detectable inorganic sulfides
tephric material	≥ 30% (by grain count) of volcanic glass and related materials

Structure

Each RSG of the WRB is provided with a listing of possible principal and supplementary qualifiers, from which the user can construct the second level of the classification. The principal qualifiers are given in a priority sequence. The broad principles that govern the WRB class differentiation are:

- At the ***first level*** (RSGs), classes are differentiated mainly according to characteristic soil features produced by primary pedogenetic process, except where *special soil parent materials* are of overriding importance.

- At the ***second level*** (RSGs with qualifiers), soils are differentiated according to soil features resulting from any secondary soil-forming process that has significantly affected the primary characteristics. In many cases, soil characteristics that have a significant effect on land use are taken into account.

Evolution of the system

The Revised Legend of the FAO/UNESCO Soil Map of the World (FAO, 1988) was used as a basis for the development of the WRB in order to take advantage of the international soil correlation that had already been conducted through this project and elsewhere. The first edition of the WRB, published in 1998, comprised 30 RSGs; the second edition published in 2006 and the current (third) edition both have 32 RSGs.

1.5 ARCHITECTURE

The WRB comprises two levels of categorical detail:

1. the ***First Level*** having 32 Reference Soil Groups (RSGs);

2. the ***Second Level***, consisting of the name of the RSG combined with a set of principal and supplementary qualifiers.

First Level: The Reference Soil Groups

Table 2 provides an overview of the RSGs and the rationale for the sequence of the RSGs in the WRB Key. The RSGs are allocated to groups on the basis of dominant identifiers, i.e. the soil-forming factors or processes that most clearly condition the soil.

Second Level: The Reference Soil Groups with their qualifiers

In the WRB, a distinction is made between **principal qualifiers** and **supplementary qualifiers**. Principal qualifiers are regarded as being most significant for a further characterization of soils of the particular RSG. They are given in a ranked order. Supplementary qualifiers give some further details about the soil. They are not ranked, but listed alphabetically. Chapter 2 gives the rules for the use of qualifiers for naming soils and for creating map legends.

Constructing the second level by adding qualifiers to the RSG has several advantages compared with a dichotomic key:

- For every soil, the RSG has the appropriate number of associated qualifiers. Soils with few characteristics have short names; soils with many characteristics (e.g. polygenetic soils) have longer names.

- The WRB is capable of indicating most of the soil's properties, which are incorporated into an informative soil name.

- The system is robust. Missing data do not necessarily lead to a dramatic error in the classification of a soil. If one qualifier is erroneously added or erroneously omitted based on incomplete data, the rest of the soil name remains correct.

TABLE 2
Simplified guide to the WRB Reference Soil Groups (RSGs) with suggested codes

Note – this table is not to be used as a key. For full definitions, please refer to Chapter 3 and the Key (Chapter 4).

	RSG	Code
1. Soils with thick organic layers:	Histosols	HS
2. Soils with strong human influence –		
With long and intensive agricultural use:	Anthrosols	AT
Containing significant amounts of artefacts:	Technosols	TC
3. Soils with limitations to root growth –		
Permafrost-affected:	Cryosols	CR
Thin or with many coarse fragments:	Leptosols	LP
With a high content of exchangeable Na:	Solonetz	SN
Alternating wet-dry conditions, shrink-swell clays:	Vertisols	VR
High concentration of soluble salts:	Solonchaks	SC
4. Soils distinguished by Fe/Al chemistry –		
Groundwater-affected, underwater and in tidal areas:	Gleysols	GL
Allophanes or Al-humus complexes:	Andosols	AN
Subsoil accumulation of humus and/or oxides:	Podzols	PZ
Accumulation and redistribution of Fe:	Plinthosols	PT
Low-activity clay, P fixation, many Fe oxides, strongly structured:	Nitisols	NT
Dominance of kaolinite and oxides:	Ferralsols	FR
Stagnating water, abrupt textural difference:	Planosols	PL
Stagnating water, structural difference and/or moderate textural difference:	Stagnosols	ST
5. Pronounced accumulation of organic matter in the mineral topsoil –		
Very dark topsoil, secondary carbonates:	Chernozems	CH
Dark topsoil, secondary carbonates:	Kastanozems	KS
Dark topsoil, no secondary carbonates (unless very deep), high base status:	Phaeozems	PH
Dark topsoil, low base status:	Umbrisols	UM
6. Accumulation of moderately soluble salts or non-saline substances –		
Accumulation of, and cementation by, secondary silica:	Durisols	DU
Accumulation of secondary gypsum:	Gypsisols	GY
Accumulation of secondary carbonates:	Calcisols	CL
7. Soils with clay-enriched subsoil –		
Interfingering of coarser-textured, lighter coloured material into a finer-textured, stronger coloured layer:	Retisols	RT
Low-activity clays, low base status:	Acrisols	AC
Low-activity clays, high base status:	Lixisols	LX
High-activity clays, low base status:	Alisols	AL
High-activity clays, high base status:	Luvisols	LV

8. Soils with little or no profile differentiation –		
Moderately developed:	Cambisols	CM
Sandy:	Arenosols	AR
Stratified fluviatile, marine and lacustrine sediments:	Fluvisols	FL
No significant profile development:	Regosols	RG

1.6 TOPSOILS

Topsoil characteristics are prone to rapid change with time and are therefore used only in some cases in the WRB. Several suggestions for topsoil classification systems have been made (Broll *et al.*, 2006; Fox *et al.*, 2010; Graefe *et al.*, 2012; Jabiol *et al*. 2013). They may be combined with the WRB.

1.7 TRANSLATION INTO OTHER LANGUAGES

Translations into other languages are most welcome. For copyright, please contact FAO. However, the soil names must not be translated into any other language nor transliterated into another alphabet. Soil names must preserve their grammatical form. The rules for the sequence of qualifiers must be followed in any translation. Names of RSGs and qualifiers start with capital letters.

Chapter 2
The rules for classifying soils and creating map legends

2.1 GENERAL RULES

Classification consists of three steps.

Step one – detecting diagnostic horizons, properties and materials

Guidelines for Soil Description (FAO, 2006) should be followed when describing the soil and its features. It is useful to compile a list of the diagnostic horizons, properties and materials observed (see Chapter 3). It is possible to make a preliminary classification of the soil in the field, using all observable or easily measurable properties and features of the soil and associated terrain. However, the final classification can be made only when analytical data are available. *Procedures for Soil Analysis* (Van Reeuwijk, 2002) should be followed in determining the chemical and physical characteristics of the soil. A summary of these is included in Annex 2.

For the classification, only the diagnostic criteria are relevant. Numerical values obtained in the field or in the laboratory have to be taken as such and must not be rounded when compared with the threshold values in the diagnostic criteria. A layer may fulfil the criteria of more than one diagnostic horizon, property or material, which are then regarded as overlapping or coinciding. If a diagnostic horizon consists of several subhorizons, the diagnostic criteria (except thickness) must be fulfilled in every subhorizon separately (averages are not calculated), unless specified otherwise.

Step two – allocating the soil to a Reference Soil Group

The described combination of diagnostic horizons, properties and materials is compared to the WRB Key (Chapter 4) in order to allocate the soil to the appropriate **Reference Soil Group (RSG)**. The user should go through the Key systematically, starting at the beginning and excluding one by one all RSGs for which the specified requirements are not met. The soil belongs to the first RSG for which it fulfils the criteria.

Step three – allocating the qualifiers

For the second level of the WRB classification, qualifiers are used. The qualifiers available for use with a particular RSG are listed in the Key, along with the RSG. They are divided into principal and supplementary qualifiers. The **principal qualifiers** are ranked and given in an order of importance. The **supplementary qualifiers** are not ranked, but are, as a convention, used in alphabetical order.

The principal qualifiers are added before the name of the RSG without brackets and without commas. The sequence is from right to left, i.e. the uppermost qualifier in the list is placed closest to the name of the RSG. The supplementary qualifiers are added in brackets after the name of the RSG and are separated from each other by commas. The sequence is from left to right, i.e. the first qualifier according to the alphabet is placed closest to the name of the RSG.

Qualifiers conveying redundant information are not added. For example, Eutric is not added if the Calcaric qualifier applies.

If two or more qualifiers in the list are **separated by a slash (/)** only one of them can be used. The slash signifies that these qualifiers are either mutually exclusive (e.g. Dystric and Eutric) or one of them is redundant (see above) with the redundant qualifier(s) listed after the slash(es). In the soil name, supplementary qualifiers are always placed in the order of the alphabet, even if their position in the list differs from alphabetical sequence due to the use of the slash.

Qualifiers that are mutually exclusive may apply to the same soil at different depths and can be used with the respective specifiers (see '2.4 Subqualifiers', below). If the specifiers are used with principal qualifiers, the qualifier referring to the upper layer is placed closer to the name of the RSG. If the specifiers are used with supplementary qualifiers, the alphabetical sequence is according to the qualifiers, not the subqualifiers.

If qualifiers apply but are not in the list for the particular RSG, they should be added last as supplementary qualifiers.

Qualifier names must start with capital letters.

2.2 RULES FOR CLASSIFYING SOILS

For the classification of a soil (or strictly, the allocation of a soil according to the WRB classification) at the second level, all the principal and supplementary qualifiers that apply must be added to the name of the RSG.

Example of a WRB soil classification

Field description:

A soil developed from loess with high-activity clays has a marked clay increase at 60 cm depth, clay coatings in the clay-rich horizon and a field pH value around 6 in the depth from 50 to 100 cm. The clay-poor upper soil is subdivided into a darker upper and a light-coloured lower horizon. The clay-rich horizon has a limited amount of mottling with intensive colours inside the soil aggregates and *reducing conditions* in some parts during spring time. The following conclusions can be drawn:

a.	clay increase and/or clay coatings	→ *argic* horizon
b.	*argic* horizon with high CEC and high base saturation (inferred by pH 6)	→ Luvisol
c.	light colour	→ Albic qualifier
d.	some mottles	→ *stagnic* properties
e.	*stagnic* properties and *reducing conditions* starting at 60 cm	→ Endostagnic qualifier
f.	clay coatings	→ Cutanic qualifier
g.	clay increase	→ Differentic qualifier

The field classification is:
Albic Endostagnic Luvisol (Cutanic, Differentic)

Laboratory analyses:

The laboratory analyses confirm a high CEC kg^{-1} clay in the argic horizon and a high base saturation in the depth from 50–100 cm. They further detect the texture class of silty clay loam with 30% clay (Siltic qualifier) in the topsoil and of silty clay with 45% clay (Clayic Qualifier) in the subsoil.

The final classification is:
Albic Endostagnic Luvisol (Endoclayic, Cutanic, Differentic, Episiltic)

2.3 RULES FOR CREATING MAP LEGENDS

The following rules apply:

1. A map unit consists of

    - a dominant soil only or
    - a dominant soil plus a codominant soil and/or one or more associated soils or
    - two or three codominant soils or
    - two or three codominant soils plus one or more associated soils.

    Dominant soils represent ≥ 50% of the soil cover, codominant soils ≥ 25 and < 50% of the soils cover. Associated soils represent ≥ 5 and < 25% of the soil cover, or are of high relevance in the landscape ecology.

    If codominant or associated soils are indicated, the words 'dominant:', 'codominant:' and 'associated:' are written before the name of the soil; the soils are separated by semicolons.

2. The number of qualifiers specified below refers to the dominant soil. For codominant or associated soils, fewer numbers of qualifiers (or even no qualifier) may be appropriate.

3. Depending on scale, different numbers of principal qualifiers are used:

    a. For very small map scales (e.g. smaller than 1 : 10 000 000), only the Reference Soil Group (RSG) is used.

    b. For next larger map scales (e.g. from 1 : 5 000 000 to 1 : 10 000 000), the RSG plus the first applicable principal qualifier are used.

    c. For next larger map scales (e.g. from 1 : 1 000 000 to 1 : 5 000 000), the RSG plus the first two applicable principal qualifiers are used.

    d. For next larger map scales (e.g. from 1 : 250 000 to 1 : 1 000 000), the RSG plus the first three applicable principal qualifiers are used.

4. If there are fewer qualifiers applicable than described above, the lesser number is used.

5. **Depending on the purpose of the map or according to national traditions, at any scale level, further qualifiers may be added optionally**. They may be additional principal qualifiers from further down the list and not already used in the soil name, or they may be supplementary qualifiers. They are placed using the above-mentioned rules for supplementary qualifiers. If two or more optional qualifiers are used, the following rules apply:

    a. the principal qualifiers are placed first, and of them, the first applicable qualifier is placed first, and

    b. the sequence of any supplementary qualifiers added is decided by the soil scientist who makes the map.

Examples for map units using WRB

Example 1

A map unit dominated by a soil with a very dark mineral surface horizon, 30 cm thick, with high base saturation, no secondary carbonates, clay illuviation features and groundwater influence starting at 60 cm from the mineral soil surface (i.e. having a layer, ≥ 25 cm thick, that has *gleyic* properties throughout and *reducing conditions* in some parts of every sublayer), will be named as follows:

- at the first map scale level: → Phaeozems
- at the second map scale level: → Chernic Phaeozems
- at the third map scale level: → Gleyic Chernic Phaeozems
- at the fourth map scale level: → Luvic Gleyic Chernic Phaeozems

Example 2

In a map unit, continuous rock starts at 80 cm. In 80% of the area, the soil above the *continuous rock* has less than 40% coarse fragments, in the other 20% of the area, the soil above the *continuous rock* has 85% coarse fragments. The soils are calcareous and silty. This map unit will be named as follows:

- at the first map scale level: → dominant: Regosols
→ associated: Leptosols
- at the second map scale level: → dominant: Leptic Regosols
→ associated: Hyperskeletic Leptosols
- at the third map scale level: → dominant: Calcaric Leptic Regosols
→ associated: Hyperskeletic Leptosols
- at the fourth map scale level: → dominant: Calcaric Leptic Regosols
→ associated: Hyperskeletic Leptosols

In this example, the next applicable qualifier for the Regosols is Eutric. However, as high base saturation is already indicated by the Calcaric qualifier, the Eutric qualifier is redundant. Therefore in this case, only two qualifiers are applicable at the fourth map scale level.

The high silt content may be expressed by the Siltic qualifier, which as a supplementary qualifier is optional in a map legend. However it may be added at any scale level, for example:

Regosols (Siltic)

Leptic Regosols (Siltic)

Calcaric Leptic Regosols (Siltic)

Example 3
A map unit dominated by a soil with a thick layer of strongly decomposed acidic *organic* material, 70 cm thick, with *continuous rock* at 80 cm and in an environment with a large excess of precipitation will be named as follows:

- at the first map scale level: → Histosols
- at the second map scale level: → Sapric Histosols
- at the third map scale level: → Leptic Sapric Histosols
- at the fourth map scale level: → Ombric Leptic Sapric Histosols

In this example the next applicable qualifier is Dystric. However as three qualifiers are already used, the fourth may be added as an optional qualifier. In a similar way, optional qualifiers may be used at the other scale levels:

Histosols (Sapric)

Sapric Histosols (Leptic, Ombric)

Leptic Sapric Histosols (Ombric)

Ombric Leptic Sapric Histosols (Dystric)

2.4 SUBQUALIFIERS

Qualifiers may be combined with specifiers (e.g. Epi-, Proto-) **to form subqualifiers** (e.g. Epiarenic, Protocalcic). Depending on the specifier, the subqualifier fulfils all the criteria of the respective qualifier, or it deviates in a defined way from its set of criteria. The following rules apply:

- If a subqualifier applies that fulfils all the criteria of the qualifier, the subqualifier can – but does not have to - be used instead of its qualifier (**optional subqualifiers**).
- If a subqualifier applies that fulfils all the criteria of the qualifier except thickness and/or depth criteria, the subqualifier can – but does not have to - be used, but not the qualifier (**additional subqualifiers**). Note – it may be that the qualifier is not listed with the available qualifiers for the respective RSG in Chapter 4.

- If a subqualifier applies that deviates in a defined way from the set of criteria of the qualifier, the subqualfier must be used instead of the qualifier that is listed as available for the respective RSG in Chatper 4 (**mandatory subqualifiers**). This is the case for some subqualifiers with a given definition (see below).

Optional and additional subqualifiers are recommended especially for naming soils. Their use is not recommended for principal qualifiers in map units or wherever generalization is important.

The use of specifiers does not change the position of the qualifier in the soil name with the exception of the specifiers Bathy-, Thapto-, and Proto- (see below). The alphabetical sequence of the supplementary qualifiers is according to the qualifier, not the subqualifier.

Some subqualifiers can be constructed by the user according to certain rules (see Chapter 2.4.1). Other subqualifiers have a fixed definition given in Chapter 5 (see Chapter 2.4.2).

2.4.1 SUBQUALIFIERS CONSTRUCTED BY THE USER

Constructed subqualifiers related to depth requirements

Qualifiers that have depth requirements can be combined with the specifiers **Epi-, Endo-, Amphi-, Ano-, Kato-, Panto-** and **Bathy-** to create subqualifiers (e.g. Epicalcic, Endocalcic) further expressing the depth of occurrence. If two or more of these specifiers are applicable, only the one representing the strongest expression is used (e.g. if Panto- is applicable, the others are not used). Qualifiers that are mutually exclusive at the same depth may be applicable at different depths in the same soil. Qualifiers that already have a depth range requirement of 0–50 cm or 50–100 cm from the soil surface do not require these extra depth specifiers.

Depending on the particular qualifier and the particular soil characteristics, depth-related subqualifiers are used in the following different ways:

1. If a qualifier refers to a characteristic that occurs at a **specific point of depth** (e.g. Raptic), optional subqualifiers can be constructed with the following specifiers:

    Epi- (from Greek *epi*, over): the characteristic is present somewhere ≤ 50 cm from the (mineral) soil surface and is absent > 50 and ≤ 100 cm from the (mineral) soil surface.

    Endo- (from Greek *endon*, inside): the characteristic is present somewhere > 50 and ≤ 100 cm from the (mineral) soil surface and is absent ≤ 50 cm from the (mineral) soil surface.

    Amphi- (from Greek *amphi*, around): the characteristic is present two or more times, once or more times somewhere ≤ 50 cm from the (mineral) soil surface and once or more times somewhere > 50 and ≤ 100 cm from the (mineral) soil surface.

2. If a qualifier refers to a **horizon or layer** (e.g. Calcic, Arenic, Fluvic), optional subqualifiers can be constructed with the following specifiers (see Figure 1):

Epi- (from Greek *epi*, over): the horizon or layer has its lower limit ≤ 50 cm of the (mineral) soil surface; and no such horizon or layer occurs between 50 and 100 cm of the (mineral) soil surface; and not used if the definition of the qualifier or of the horizon requires that the horizon or layer starts at the (mineral) soil surface.

Endo- (from Greek *endon*, inside): the horizon or layer starts ≥ 50 cm from the (mineral) soil surface; and no such horizon or layer occurs < 50 cm of the (mineral) soil surface. (Examples: Endocalcic: the *calcic* horizon starts ≥ 50 and ≤ 100 cm from the soil surface; Endospodic: the *spodic* horizon starts ≥ 50 and ≤ 200 cm from the mineral soil surface.)

Amphi- (from Greek *amphi*, around): the horizon or layer starts > 0 and < 50 cm of the (mineral) soil surface and has its lower limit > 50 and < 100 cm of the (mineral) soil surface; and no such horizon or layer occurs < 1 cm of the (mineral) soil surface; and no such horizon or layer occurs between 99 and 100 cm of the (mineral) soil surface.

Ano- (from Greek *ano*, upwards): the horizon or layer starts at the (mineral) soil surface, and has its lower limit > 50 and < 100 cm of the (mineral) soil surface; and no such horizon or layer occurs between 99 and 100 cm of the (mineral) soil surface.

Kato- (from Greek *kato*, downwards): the horizon or layer starts > 0 and < 50 cm of the (mineral) soil surface, and has its lower limit ≥ 100 cm of the (mineral) soil surface; and no such horizon or layer occurs < 1 cm of the (mineral) soil surface.

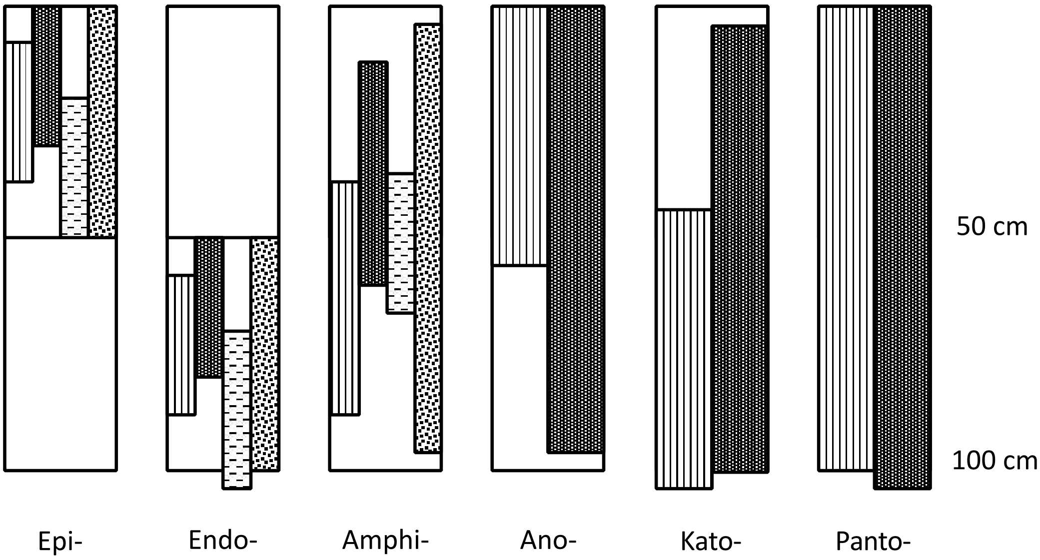
Panto- (from Greek *pan*, all): the horizon or layer starts at the (mineral) soil surface and has its lower limit ≥ 100 cm of the (mineral) soil surface.

3. If a qualifier refers to the **major part of a certain depth range or to half or more of a certain depth range** (Dystric and Eutric), optional or additional subqualifiers can be constructed with the following specifiers:

Epi- (from Greek *epi*, over): the characteristic is present in the major part (or half or more of the part) between the (mineral) soil surface (or the specified upper limit) and 50 cm from the (mineral) soil surface and is absent in the major part (or half or more of the part) between 50 and 100 cm from the (mineral) soil surface or between 50 cm from the (mineral) soil surface and *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower.

Endo- (from Greek *endon*, inside): the characteristic is present in the major part (or half or more of the part) between 50 and 100 cm from the (mineral) soil surface or between 50 cm from the (mineral) soil surface and *continuous rock*, *technic hard* material or a cemented or indurated layer, whichever is shallower, and absent in the major part (or half or more of the part) between the (mineral) soil surface (or the specified upper limit) and 50 cm from the (mineral) soil surface.

FIGURE 1
Subqualifiers related to depth requirements and referring to a particular horizon or layer.



4. If a qualifier refers to a **specified depth range throughout** (e.g. Calcaric), additional subqualifiers can be constructed with the following specifiers:

    Epi- (from Greek *epi*, over): the characteristic is present throughout between the (mineral) soil surface (or the specified upper limit) and 50 cm from the (mineral) soil surface and is absent in some layer between 50 and 100 cm from the (mineral) soil surface.

    Endo- (from Greek *endon*, inside): the characteristic is present throughout between 50 and 100 cm from the (mineral) soil surface or between 50 cm from the (mineral) soil surface and *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower, and is absent in some layer ≤ 50 cm from the (mineral) soil surface.

5. If a qualifier refers to a **percentage** (e.g. Skeletic), additional subqualifiers can be constructed with the following specifiers:

    Epi- (from Greek *epi*, over): the characteristic is present between the (mineral) soil surface and 50 cm from the (mineral) soil surface but is not present throughout i.e. if averaged over a depth of 100 cm from the (mineral) soil surface or between the (mineral) soil surface and *continuous rock*, *technic hard* material or a cemented or indurated layer, whichever is shallower.

    Endo- (from Greek *endon*, inside): the characteristic is present between 50 and 100 cm from the (mineral) soil surface or between 50 cm from the (mineral) soil surface and *continuous rock*, *technic hard* material or a cemented or indurated layer, whichever is shallower, but is not present throughout i.e. if averaged over a depth of 100 cm from the (mineral) soil surface or between the (mineral) soil surface and *continuous rock*, *technic hard* material or a cemented or indurated layer, whichever is shallower.

6. If a qualifier refers to a specific point of depth or to a horizon or layer, but its criteria are only fulfilled if layers at a depth of > 100 cm from the (mineral) soil surface are taken into account, the **Bathy-** (from Greek *bathys*, deep) specifier can be used to construct an additional subqualifier. The Bathy- subqualifier extends to a greater depth than specified for the qualifier. If the Endo- specifier cannot be added to a qualifier, the Bathy- specifier cannot be used either (e.g. Alcalic: neither Endo-, nor Bathy-). If used with a principal qualifier, the Bathy- subqualifier **must shift to the supplementary qualifiers**. The Bathy- subqualifiers are placed after the supplementary qualifiers that are listed for the respective RSG. With the Bathy- specifier, qualifiers that are not even in the list for the particular RSG (see Chapter 4) can be added, for example Albic Arenosol (Bathylixic). If it comprises buried layers, Bathy- is only allowed in combination with the Thapto- specifier, e.g. Bathythaptovertic (see the Thapto- specifier, below, and '2.5 Buried soils', below).

Note: For every qualifier with depth requirements, the definition (Chapter 5) specifies whether the depth requirement refers **to the soil surface or to the mineral soil surface**.

Note: Specifiers conveying redundant information are not added. For example: Skeletic Epileptic Cambisol, not: Episkeletic Epileptic Cambisol.

Constructed subqualifiers for other requirements

If a diagnostic horizon or a layer with a diagnostic property belongs to a buried soil (see '2.5 Buried soils', below), the **Thapto-** (from Greek *thaptein*, to bury) specifier can be used to construct optional or additional subqualifiers. If used with a principal qualifier, the Thapto- subqualifier **must shift to the supplementary qualifiers**. The Thapto- subqualifiers are placed after the supplementary qualifiers that are listed for the respective RSG and after any Bathy- subqualifier.

For soils with *technic hard* material, a geomembrane, a continuous layer of *artefacts*, *contiunuous rock* or a cemented or indurated layer, subqualifiers with the **Supra-** (from Latin *supra*, above) specifier can be constructed to describe the soil material above, if the thickness or depth requirements of a qualifier or of its respective diagnostics are not fulfilled, but all other criteria are fulfilled throughout in the soil material above (e.g. Ekranic Technosol (Suprafolic)). If the Supra- specifier is used, the Epi- specifier is not used.

2.4.2 SUBQUALIFIERS WITH A GIVEN DEFINITION

For some qualifiers, subqualifiers are defined in Chapter 5, e.g. Hypersalic and Protosalic for the Salic qualifier. These **subqualifiers are not listed with the RSGs in Chapter 4** (unless the qualifier without specifier cannot exist for the respective RSG). They belong to the optional (e.g. Hypercalcic, Hypocalcic, Orthomineralic), the additional (e.g. Akromineralic) or the mandatory (e.g. Protocalcic) subqualifiers. If the **Proto-** specifier is used with a principal qualifier, the Proto- subqualifier **must shift to the supplementary qualifiers** and be placed within the list of the supplementary qualifiers according to the alphabetical position of the qualifier, not the subqualifier.

If of one qualifier, two or more subqualifiers with a given definition apply (e.g. Anthromollic and Tonguimollic), they have to be listed all. Adding a further specifier to a subqualifier with a given definition is also allowed, e.g. Endoprotosalic, Supraprotosodic.

2.5 BURIED SOILS

A buried soil is a soil covered by younger deposits. Where a soil is buried, the following rules apply:

1. The overlying material and the buried soil are classified as one soil if both together qualify as a Histosol, Anthrosol, Technosol, Cryosol, Leptosol, Vertisol, Gleysol, Andosol, Planosol, Stagnosol, Arenosol, Fluvisol or Regosol.
2. Otherwise, the overlying material is classified with preference if it is ≥ 50 cm thick or if the overlying material, if it stood alone, satisfies the requirements of a Folic Regosol or of a RSG other than a Regosol. For depth requirements in the overlying material, the lower limit of the overlying material is regarded as if it were the upper limit of *continuous rock*.
3. In all other cases, the buried soil is classified with preference. For depth requirements in the buried soil, the upper limit of the buried soil is regarded as its soil surface.
4. If the overlying soil is classified with preference, the name of the buried soil is placed after the name of the overlying soil adding the word ‘over’ in between, e.g. Skeletic Umbrisol (Siltic) over Albic Podzol (Arenic). As many buried soils are polygenetic, qualifiers that are not in the list for the particular RSG may be applicable. If so, these qualifiers must be used as supplementary qualifiers. The qualifiers Infraandic and Infraspodic are provided for buried soils only and are therefore not listed with the RSGs in Chapter 4. Alternatively, instead of the buried soil, a buried diagnostic horizon or a buried layer with a diagnostic property can be added with the Thapto- subqualifier to the name of the overlying soil (see ‘2.4 Subqualifiers’, above).
5. If the buried soil is classified with preference, the overlying material is indicated with the Novic qualifier, and if applicable, with the qualifiers Aeolic, Akrofluvic, Colluvic or Transportic.

Chapter 3
Diagnostic horizons, properties and materials

Before using the diagnostic horizons, properties and materials, please read the 'Rules for classifying soils' (Chapter 2).

Diagnostic horizons and *properties* are characterized by a combination of attributes that reflect widespread, common results of the processes of soil formation (Bridges, 1997) or indicate specific conditions of soil formation. Their features can be observed or measured, either in the field or the laboratory, and require a minimum or maximum expression to qualify as diagnostic. In addition, diagnostic horizons require a certain thickness, thus forming a recognizable layer in the soil.

Diagnostic materials are materials that significantly influence pedogenetic processes or are indicative of them.

Throughout the following text, references to the RSGs defined in Chapter 4 and the diagnostic features listed elsehere in this Chapter are shown in *italics*.

DIAGNOSTIC HORIZONS

Anthraquic horizon

General description

An anthraquic horizon (from Greek *anthropos*, human, and Latin *aqua*, water) is a surface horizon modified by human activity (wet cultivation) that comprises a *puddled layer* and a *plough pan.*

Diagnostic criteria

An anthraquic horizon is a surface horizon consisting of *mineral* material and has:

1. a puddled layer with the following Munsell colours, moist, in ≥ 80% of the exposed area:

   a hue of 7.5YR or yellower, a value of ≤ 4 and a chroma of ≤ 2; ***or***

   a hue of GY, B or BG and a value of ≤ 4; ***and***

2. a plough pan underlying the puddled layer, with all of the following:

   a. one or both of the following:

      i. a platy structure in ≥ 25% of its volume; ***or***

      ii. a massive structure in ≥ 25% of its volume; ***and***

b. a bulk density higher by ≥ 10% (relative) than that of the puddled layer; ***and***

c. yellowish-brown, brown or reddish-brown iron-manganese mottles or coatings around root channels, and if soil aggregates are present, at or near the surfaces of the aggregates; ***and***

3. a thickness of ≥ 15 cm.

Field identification

An anthraquic horizon shows evidence of reduction and oxidation owing to flooding for part of the year. When not flooded, it is very dispersible and has a loose packing of sorted small soil aggregates. The plough pan is compact, has a platy or massive structure and a very low infiltration rate. It has a reduced matrix and yellowish-brown, brown or reddish-brown rusty mottles along cracks and root channels due to oxygen release from plant roots.

Argic horizon

General description

An argic horizon (from Latin *argilla*, white clay) is a subsurface horizon with distinctly higher clay content than the overlying horizon. The textural differentiation may be caused by:

- an illuvial accumulation of clay,
- predominant pedogenetic formation of clay in the subsoil,
- destruction of clay in the surface horizon,
- selective surface erosion of clay,
- upward movement of coarser particles due to swelling and shrinking,
- biological activity, or
- a combination of two or more of these different processes.

Sedimentation of surface materials that are coarser than the subsurface horizon may enhance a pedogenetic textural differentiation. However, textural difference due only to a lithic 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 their pathways of development to be traced (Sombroek, 1986).

Diagnostic criteria

An argic horizon consists of *mineral* material and:

1. has a texture class of loamy sand or finer and ≥ 8% clay; ***and***
2. one or both of the following:

a. has an overlying coarser textured horizon with all of the following:

i. the coarser textured horizon is not separated from the argic horizon by a *lithic discontinuity*; ***and***

ii. if the coarser textured horizon directly overlies the argic horizon, its lowermost subhorizon does not form part of a plough layer; ***and***

iii. if the coarser textured horizon does not directly overlie the argic horizon, the transitional horizon between the coarser textured horizon and the argic horizon has a thickness of ≤ 15 cm; ***and***

iv. if the coarser textured horizon has < 10% clay in the fine earth fraction, the argic horizon has ≥ 4% (absolute) more clay; ***and***

v. if the coarser textured horizon has ≥ 10 and < 50% clay in the fine earth fraction, the ratio of clay in the argic horizon to that of the coarser textured horizon is ≥ 1.4; ***and***

vi. if the coarser textured horizon has ≥ 50% clay in the fine earth fraction, the argic horizon has ≥ 20% (absolute) more clay; ***or***

b. has evidence of illuvial clay in one or more of the following forms:

i. oriented clay bridging between ≥ 5% of the sand grains; ***or***

ii. clay coatings lining ≥ 5% of the surfaces in pores; ***or***

iii. clay coatings covering ≥ 5% of the vertical and ≥ 5% of the horizontal surfaces of soil aggregates; ***or***

iv. in thin sections, oriented clay bodies that constitute ≥ 1% of the section; ***or***

v. a coefficient of linear extensibility (COLE) of ≥ 0.04, and a ratio of fine clay[2] to total clay in the argic horizon greater by ≥ 1.2 times than the ratio in the overlying coarser textured horizon; ***and***

3. both of the following:

a. does not form part of a *natric* horizon; ***and***

b. does not form part of a *spodic* horizon, unless illuvial clay is evidenced by one or more of the diagnostic criteria listed under 2.b.; ***and***

4. has a thickness of one-tenth or more of the thickness of the overlying *mineral* material, if present, and one of the following:

a. ≥ 7.5 cm (combined thickness if composed of lamellae) if the argic horizon has a texture class of sandy loam or finer; ***or***

b. ≥ 15 cm (combined thickness if composed of lamellae).

[2] Fine clay: < 0.2 µm equivalent diameter.

Field identification

Textural differentiation is the main feature for recognition of argic horizons. The illuvial nature of the argic horizon may be established using a ×10 hand lens. If clay coatings occur on soil aggregate surfaces, in fissures, in pores and in channels – illuvial argic horizons show clay coatings on at least 5% of both horizontal and vertical aggregate faces, and in the pores.

In shrink-swell soils, clay coatings are easily confused with pressure faces (stress cutans). Clay coatings in protected positions, for example in pores, contribute to 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 show areas with oriented clays that constitute on average ≥ 1% 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/total clay ratio. In illuvial argic horizons, the fine clay to total clay ratio is larger than in the overlying horizons, due to preferential eluviation of fine clay particles.

If the soil shows a *lithic discontinuity* directly over the argic horizon, or if the surface horizon has been removed by erosion, or if a plough layer directly overlies the argic horizon, then the illuvial nature must be clearly established (diagnostic criterion 2b).

The argic horizon may be subdivided into several lamellae with coarser-textured layers in between.

Relationships with some other diagnostics

Argic horizons are normally situated below eluvial horizons i.e. horizons from which clay and Fe 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. Afterwards, new sediments may be added.

Some argic horizons fulfil all the diagnostic criteria of the *ferralic* horizon. Some argic horizons fulfil most of the criteria of the *ferralic* horizon but fail diagnostic criterion 3 of the *ferralic* horizon, which requires < 10% water-dispersible clay or *geric* properties or ≥ 1.4% *soil organic carbon*. Ferralsols must have a *ferralic* horizon and may have an argic horizon as well, which may or may not overlap with the *ferralic* horizon; but if an argic horizon is present, it must have in its upper 30 cm: < 10% water-dispersible clay or *geric* properties or ≥ 1.4% *soil organic carbon*.

Argic horizons lack the sodium saturation characteristics of the *natric* horizon.

Argic horizons in cool and moist, freely drained soils of high plateaus and mountains in tropical and subtropical regions may occur in association with *sombric* horizons.

Calcic horizon

General description

A calcic horizon (from Latin *calx*, lime) is a horizon in which secondary calcium carbonate ($CaCO_3$) has accumulated in a diffuse form (calcium carbonate occurs as impregnation of the matrix or in the form of fine calcite particles of < 1 mm, dispersed in the matrix) or as discontinuous concentrations (veins, pseudomycelia, coatings, soft and/or hard nodules).

The accumulation usually occurs in a subsurface horizon, in the parent material, or more rarely, in surface horizons. The calcic horizon may contain primary carbonates as well.

Diagnostic criteria

A calcic horizon:

1. has a calcium carbonate equivalent in the fine earth fraction of ≥ 15%; ***and***
2. has one or both of the following:
   a. ≥ 5% (by volume) secondary carbonates; ***or***
   b. a calcium carbonate equivalent in the fine earth fraction of ≥ 5% higher (absolute, by mass) than that of an underlying layer and no *lithic discontinuity* between the two layers; ***and***
3. does not form part of a *petrocalcic* horizon; ***and***
4. has a thickness of ≥ 15 cm.

Field identification

Calcium carbonate can be identified in the field using 1 *M* hydrochloric acid (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. When foam develops after adding 1 *M* HCl, it indicates a calcium carbonate equivalent near to or > 15%.

Other possible indications of a calcic horizon are:

- white, pinkish to reddish, or grey colours (if not overlapping horizons rich in organic carbon), and
- a low porosity (interaggregate porosity is usually less than in the horizon directly above, and possibly also less than in the horizon directly below).

Calcium carbonate content may decrease with depth, but this is difficult to establish in some places, particularly where the calcic horizon occurs in the deeper subsoil. Therefore, a certain accumulation of secondary carbonates is sufficient to diagnose a calcic horizon.

Additional characteristics

Determination of the amount of calcium carbonate (by mass) and the changes of calcium carbonate content within the soil profile are the main analytical criteria for establishing the presence of a calcic horizon. Determination of pH_{water} enables distinction between accumulations with a basic (*calcic*) character (pH 8–8.7) due to the dominance of $CaCO_3$, and those with an ultrabasic (*non-calcic*) character (pH > 8.7) because of the presence of Na_2CO_3 and/or $MgCO_3$.

In addition, the analysis of thin sections may reveal the presence of dissolution forms in horizons above or below a calcic horizon, evidence of silicate epigenesis (calcite pseudomorphs after primary minerals), or the presence of other calcium carbonate pedofeatures, while clay mineralogical analyses of calcic horizons often show clays characteristic of confined environments, such as smectite, palygorskite and sepiolite.

If the accumulation of soft carbonates is such that all or most of the soil and/or rock structure disappears and continuous concentrations of calcium carbonate prevail, the Hypercalcic qualifier is used.

Relationships with some other diagnostics

When calcic horizons become indurated, transition takes place to the *petrocalcic* horizon, the expression of which may be massive or platy. A calcic horizon and a *petrocalcic* horizon may overlie each other. Less pronounced accumulations of secondary carbonates, not qualifying for a calcic horizon, may fulfil the diagnostic criteria of *protocalcic* properties. *Calcaric* material refers to primary carbonates.

In dry regions and in the presence of sulfate-bearing soil or groundwater solutions, calcic horizons occur associated with *gypsic* horizons. Calcic and *gypsic* horizons typically (but not always) occupy different positions in the soil profile because gypsum is more soluble than calcium carbonate, and they can normally be distinguished clearly from each other by a difference in crystal morphology. Gypsum crystals tend to be needle-shaped, usually visible to the naked eye, whereas pedogenetic calcium carbonate crystals are much finer in size.

Cambic horizon

General description

A cambic horizon (from Late Latin *cambiare*, to change) is a subsurface horizon showing evidence of pedogenetic alteration that ranges from weak to relatively strong. The cambic horizon has lost, at least in half of the volume of the fine earth fraction, its original rock structure. If the underlying layer has the same parent material, the cambic horizon usually shows higher oxide and/or clay contents than this underlying layer and/or evidence of removal of carbonates and/or gypsum. The pedogenetic alteration of a cambic horizon can also be established by contrast with one of the overlying mineral horizons that are generally richer in organic matter and therefore have a darker and/or less intense colour. In this case, some soil structure development is needed to prove pedogenetic alteration.

Diagnostic criteria

A cambic horizon consists of *mineral* material and:

1. has a texture class of

    a. sandy loam or finer; ***or***

    b. very fine sand or loamy very fine sand[3]; ***and***

2. has absence of rock structure in ≥ 50% of the volume of the fine earth fraction; ***and***

3. shows evidence of pedogenetic alteration in one or more of the following:

    a. when compared to the directly underlying layer, if it is not separated from the

[3] Very fine sand and loamy very fine sand: The texture class is sand or loamy sand and ≥ 50% of the sand fraction is < 125 μm and < 25% of the sand fraction is ≥ 630 μm (see texture classes, Annex 4).

cambic horizon by a *lithic discontinuity,* one or more of the following:

   i. a Munsell colour hue ≥ 2.5 units redder, moist; ***or***

   ii. a Munsell colour chroma ≥ 1 unit higher, moist; ***or***

   iii. a clay content ≥ 4% (absolute) higher; ***or***

b. soil aggregate structure in ≥ 50% of the volume of the fine earth fraction ***and*** when compared to an overlying mineral layer, if it is not separated from the cambic horizon by a *lithic discontinuity,* one or more of the following:

   i. a Munsell colour hue ≥ 2.5 units redder, moist; ***or***

   ii. a Munsell colour value ≥ 1 unit higher, moist; ***or***

   iii. a Munsell colour chroma ≥ 1 unit higher, moist; ***or***

c. compared to the directly underlying layer, if it is not separated from the cambic horizon by a *lithic discontinuity,* evidence of removal of carbonates or gypsum by one or more of the following:

   i. ≥ 5% (by mass, absolute, fine earth fraction) less carbonates or gypsum; ***or***

   ii. if all coarse fragments in the underlying layer are completely coated with carbonates, some of these fragments in the cambic horizon are partly free of coatings; ***or***

   iii. if the coarse fragments in the underlying layer are coated with carbonates only on their underside, those in the cambic horizon are free of coatings; ***and***

4. does not form part of a plough layer and does not form part of an *anthraquic, argic, calcic, duric, ferralic, fragic, gypsic, hortic, hydragric, irragric, mollic, natric, nitic, petrocalcic, petroduric, petrogypsic, petroplinthic, pisoplinthic, plaggic, plinthic, pretic, salic, sombric, spodic, umbric, terric* or *vertic* horizon; ***and***

5. has a thickness of ≥ 15 cm.

Relationships with some other diagnostics

The cambic horizon can be considered the predecessor of many other diagnostic horizons, all of which have specific properties that are not recognized in the cambic horizon – such as illuvial or residual accumulations, removal of substances other than carbonates or gypsum, accumulation of soluble components, or the development of specific soil structure.

Cambic horizons in cool and moist, freely drained soils of high plateaus and mountains in tropical and subtropical regions may occur in association with *sombric* horizons.

Chernic horizon

General description

A chernic horizon (from Russian *chorniy*, black) is a relatively thick, well-structured, very dark-coloured surface horizon, with a high base saturation, a high biological activity and a moderate to high content of organic matter.

Diagnostic criteria

A chernic horizon is a surface horizon consisting of *mineral* material and has:

1. ≥ 20% (by volume, weighted average) of fine earth; ***and***
2. granular or fine subangular blocky soil structure; ***and***
3. ≥ 1% *soil organic carbon*; ***and***
4. one or both of the following:
   a. in slightly crushed samples a Munsell colour value of ≤ 3 moist, and ≤ 5 dry, and a chroma of ≤ 2 moist; ***or***
   b. all of the following:
      i. ≥ 40% (by mass) calcium carbonate equivalent in the fine earth fraction and/or a texture class of loamy sand or coarser; ***and***
      ii. in slightly crushed samples a Munsell colour value of ≤ 5 and a chroma of ≤ 2, both moist; ***and***
      iii. ≥ 2.5% *soil organic carbon*; ***and***
5. ≥ 1% (absolute) more *soil organic carbon* than the parent material, if parent material is present, that has a Munsell colour value of ≤ 4, moist; ***and***
6. a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 50% on a weighted average, throughout the entire thickness of the horizon; ***and***
7. a thickness of ≥ 25 cm.

Field identification

A chernic horizon may easily be identified by its blackish colour, caused by the accumulation of organic matter, its well-developed granular or fine subangular blocky structure, an indication of high base saturation (e.g. $pH_{water} > 6$), and its thickness.

Relationships with some other diagnostics

The chernic horizon is a special case of the *mollic* horizon with a higher content of *soil organic carbon*, a lower chroma, generally better developed soil structure, a minimum content of fine earth and a greater minimum thickness. The upper limit of the content of *soil organic carbon* is 20%, which is the lower limit for *organic* material.

Cryic horizon

General description

A cryic horizon (from Greek *kryos*, cold, ice) is a perennially frozen soil horizon in *mineral* or *organic* materials.

Diagnostic criteria

A cryic horizon has:

1. continuously for ≥ 2 consecutive years one of the following:
   a. massive ice, cementation by ice or readily visible ice crystals; ***or***
   b. a soil temperature of ≤ 0 °C and insufficient water to form readily visible ice crystals; ***and***
2. a thickness of ≥ 5 cm.

Field identification

Cryic horizons occur in areas with permafrost[4] and show evidence of perennial ice segregation, often associated with evidence of cryogenic processes (mixed soil material, disrupted soil horizons, involutions, organic intrusions, frost heave, separation of coarse from fine soil materials, cracks) above the cryic horizon and/or patterned surface features (earth hummocks, frost mounds, stone circles, stripes, nets and polygons).

Soils that contain saline water do not freeze at 0 °C. In order to develop a cryic horizon, such soils must be cold enough to freeze.

To identify features of cryoturbation, sorting or thermal contraction, a soil profile should intersect different elements of patterned ground, if any, or be wider than 2 m.

Engineers distinguish between *warm* and *cold* permafrost. *Warm* permafrost has a temperature higher than -2 °C and has to be considered unstable. *Cold* permafrost has a temperature of -2 °C or lower and can be used more safely for construction purposes provided the temperature remains under control.

Relationships with some other diagnostics

Cryic horizons may fulfil the diagnostic criteria of *histic*, *folic* or *spodic* horizons and may occur in association with *salic*, *calcic*, *mollic* or *umbric* horizons. In cold arid regions, *aridic* or *yermic* properties may be present.

Duric horizon

General description

A duric horizon (from Latin *durus*, hard) is a subsurface horizon showing weakly cemented to indurated nodules or concretions cemented by silica (SiO_2), presumably in the form of opal and microcrystalline silica (*durinodes*). Durinodes often have carbonate coatings that have to be removed with HCl before slaking the durinodes with potassium hydroxide (KOH).

Diagnostic criteria

A duric horizon consists of *mineral* material and has:

1. ≥ 10% (by volume) of weakly cemented to indurated, silica-enriched nodules (durinodes) or fragments of a broken-up *petroduric* horizon that show all of

[4] Permafrost: layer of soil or rock, at some depth beneath the surface, in which the temperature has been continuously below 0 °C for at least some years. It exists where summer heating fails to reach the base of the layer of frozen ground. Arctic Climatology and Meteorology Glossary, National Snow and Ice Data Center, Boulder, USA (*http://nsidc.org*).

the following:

a. when air-dry, < 50% (by volume) slake in 1 *M* HCl even after prolonged soaking, but ≥ 50% slake in concentrated KOH, concentrated NaOH or in alternating acid and alkali; ***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; ***and***

2. a thickness of ≥ 10 cm.

Additional characteristics
Dry durinodes do not slake appreciably in water, but prolonged soaking can result in the breaking-off of very thin platelets and 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 diagnostics
In arid regions, duric horizons occur in association with *gypsic*, *petrogypsic*, *calcic* and *petrocalcic* horizons.

Ferralic horizon
General description
A ferralic horizon (from Latin *ferrum*, iron, and *alumen*, alum) is a subsurface horizon resulting from long and intense weathering. The clay fraction is dominated by low-activity clays and contains various amounts of resistant minerals such as (hydr-)oxides of Fe, Al, Mn and titanium (Ti). There may be a marked residual accumulation of quartz in silt and sand size particles. Ferralic horizons normally have < 10% water-dispersible clay. Occasionally they may have more water-dispersible clay, but at the same time will display *geric* properties or a relatively high content of organic carbon.

Diagnostic criteria
A ferralic horizon consists of *mineral* material and:

1. has a texture class of sandy loam or finer and < 80% (by volume) coarse fragments, *pisoplinthic* concretions or nodules or remnants of a *petroplinthic* horizon; ***and***

2. has a CEC (by 1 *M* NH_4OAc, pH 7) of < 16 $cmol_c\ kg^{-1}$ clay and a sum of exchangeable bases (by 1 *M* NH_4OAc, pH 7) plus exchangeable Al (by 1 *M* KCl, unbuffered) of < 12 $cmol_c\ kg^{-1}$ clay; ***and***

3. has one or more of the following:

a. < 10% water-dispersible clay; ***or***

b *geric* properties; ***or***

c. ≥ 1.4% *soil organic carbon*; ***and***

4. has < 10% (by grain count) weatherable minerals[5] in the 0.05–0.2 mm fraction; ***and***

5. does not have *andic* or *vitric* properties; ***and***

6. has a thickness of ≥ 30 cm.

Field identification

Ferralic horizons are associated with old and stable landforms. The macrostructure seems to be moderate to weak at first sight but typical ferralic horizons have a strong microaggregation.

Ferralic horizons rich in Fe oxides (especially rich in hematite) have usually a friable consistence and the disrupted, dry soil material flows like flour between the fingers. Lumps of ferralic horizons are usually relatively light in mass because of the low bulk density; many ferralic horizons give a hollow sound when tapped, indicating high porosity.

If the ferralic horizon has less hematite and a more yellowish colour, it typically shows a higher bulk density and a lower porosity. It is massive or has a weak subangular blocky structure and a hard or firm consistence.

Indicators of clay illuviation such as clay coatings are generally absent, as are pressure faces and other stress features. Boundaries of a ferralic horizon are normally gradual to diffuse and little variation in colour or particle-size distribution within the horizon can be detected.

Additional characteristics

As an alternative to the weatherable minerals requirement, a total reserve of bases (TRB = exchangeable plus mineral calcium [Ca], magnesium [Mg], potassium [K] and sodium [Na]) of < 25 $cmol_c$ kg^{-1} soil may be indicative.

Relationships with some other diagnostics

Some *argic* horizons fulfil all the diagnostic criteria of the ferralic horizon. Some other *argic* horizons fulfil most of the criteria of the ferralic horizon but fail diagnostic criterion 3.

Al_{ox}, Fe_{ox}, Si_{ox} in ferralic horizons are very low, which sets them apart from the *nitic* horizons and layers with *andic* or *vitric* properties.

Some *cambic* horizons have a low CEC; however, the amount of weatherable minerals or the TRB is too high for a ferralic horizon. Such horizons represent an advanced stage of weathering and a transition to the ferralic horizon.

Ferralic horizons in cool and moist, freely drained soils of high plateaus and mountains in tropical and subtropical regions may occur in association with *sombric* horizons.

[5] Examples of minerals that are included in the meaning of *weatherable minerals* are all 2:1 phyllosilicates, chlorite, sepiolites, palygorskite, allophane, 1:1 trioctahedral phyllosilicates (serpentines), feldspars, feldspathoids, ferromagnesian minerals, glass, zeolites, dolomite and apatite. The intent of the term *weatherable minerals* is to include those minerals that are unstable in humid climates compared with other minerals, such as quartz and 1:1 lattice clays, but that are more resistant to weathering than calcite (Soil Survey Staff, 1999).

Due to redox processes, ferralic horizons may develop into *plinthic* horizons. Most *plinthic* horizons also fulfil the diagnostic criteria of ferralic horizons.

Ferric horizon

General description

A ferric horizon (from Latin *ferrum*, iron) is one in which segregation of Fe (or Fe and Mn) has taken place to such an extent that large mottles or discrete concretions or nodules have formed and the matrix between mottles, concretions or nodules is largely depleted of Fe and Mn. They do not necessarily have enhanced Fe (or Fe and Mn) contents, but Fe (or Fe and Mn) are concentrated in mottles or concretions or nodules. Generally, such segregation leads to poor aggregation of the soil particles in Fe- and Mn-depleted zones and compaction of the horizon. The segregation is the result of redox processes that may be active or relict.

Diagnostic criteria

A ferric horizon consists of *mineral* material and:

1. has one or both of the following:

    a. ≥ 15% of the exposed area occupied by coarse mottles (≥ 20 mm in diameter) that are black or have a Munsell colour hue redder than 7.5YR and a chroma of ≥ 5, both moist; ***or***

    b. ≥ 5% of the volume consisting of discrete reddish to blackish concretions and/or nodules with a diameter of ≥ 2 mm, with at least the exteriors of the concretions or nodules being at least weakly cemented or indurated, and if not black, the exteriors having redder hue or stronger chroma than the interiors; ***and***

2. does not form part of a *petroplinthic*, *pisoplinthic* or *plinthic* horizon; ***and***

3. has a thickness of ≥ 15 cm.

Relationships with some other diagnostics

In tropical or subtropical regions, ferric horizons may grade laterally into *plinthic* horizons. In *plinthic* horizons, the amount of concretions or nodules or mottles reaches ≥ 15% (by volume). Additionally, in *plinthic* horizons, a certain content of Fe_{dith} is exceeded and/or the concretions or nodules or mottles harden irreversibly to hard concretions or nodules or a hardpan on exposure to repeated wetting and drying with free access of oxygen. If the amount of hard concretions or nodules reaches ≥ 40%, it is a *pisoplinthic* horizon.

Folic horizon

General description

A folic horizon (from Latin *folium*, leaf) is a surface horizon, or a subsurface horizon occurring at a shallow depth, that consists of well-aerated *organic* material. They predominantly occur in cool climate or at high elevation.

Diagnostic criteria

A folic horizon consists of *organic* material and:

1. is saturated with water for < 30 consecutive days in most years and is not drained; ***and***

2. has a thickness of ≥ 10 cm.

Relationships with some other diagnostics

The folic horizon has similar characteristics to the *histic* horizon; however, the *histic* horizon is 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.

The lower limit of 20% *soil organic carbon* sets the folic horizon apart from *chernic*, *mollic* or *umbric* horizons, which have these contents as upper limits. Folic horizons may show *andic* or *vitric* properties.

Fragic horizon

General description

A fragic horizon (from Latin *fragilis*, fragile) is a natural non-cemented subsurface horizon with a structure 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 consists of *mineral* material and:

1. shows structural units that do not allow roots to enter; separations between these units have an average horizontal spacing of ≥ 10 cm; ***and***

2. shows evidence of alteration as defined in the cambic horizon, at least on the faces of structural units; ***and***

3. contains < 0.5% (by mass) *soil organic carbon*; ***and***

4. shows in ≥ 50% of the volume slaking or fracturing of air-dry clods, 5–10 cm in diameter, within ≤ 10 minutes when placed in water; ***and***

5. does not cement upon repeated wetting and drying; ***and***

6. has a penetration resistance at field capacity of ≥ 4 MPa in ≥ 90% of the volume; ***and***

7. does not show effervescence after adding a 1 *M* HCl solution; ***and***

8. has a thickness of ≥ 15 cm.

Field identification

A fragic horizon has a prismatic and/or blocky structure. The inner parts of the structural units may have a relatively high total porosity but, as a result of a dense outer rim, there is no continuity between the intraped pores and the interped pores and fissures. The result is a closed box system with ≥ 90% of the soil volume that cannot be explored by roots and is not percolated by water.

It is essential that the required soil volume be inspected from both vertical and horizontal sections; horizontal sections often reveal polygonal structures. Three or four such polygons (or a cut up to 1 m^2) are sufficient to test the volumetric basis for the definition of the fragic horizon.

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 structural units are hard to extremely hard; moist ones are firm to extremely firm; moist consistence may be brittle. A structural unit from a fragic horizon tends to rupture suddenly under pressure rather than to undergo slow deformation.

The fragic horizon has little active faunal activity, except occasionally between the structural units.

Relationships with some other diagnostics

A fragic horizon may underlie (but not necessarily directly), *albic* material or a *cambic*, *spodic* or *argic* horizon, unless the soil has been truncated. It can overlap partly or completely with an *argic* horizon. The fragic horizon may show *retic* properties or *albeluvic glossae*, especially in its upper part. Moreover, fragic horizons can have *reducing conditions* and *stagnic* properties.

Fulvic horizon

General description

A fulvic horizon (from Latin *fulvus*, dark yellow) is a thick, dark-coloured horizon at or near the soil surface that is typically associated with short-range-order minerals (commonly allophane) or with organo-aluminium complexes. It has a low bulk density and contains highly humified organic matter that shows a lower ratio of humic acids to fulvic acids compared with the *melanic* horizon.

Diagnostic criteria

A fulvic horizon has:

1. *andic* properties; ***and***

2. one or both of the following:

    a. a Munsell colour value or chroma of > 2, moist; ***or***

    b. a melanic index[6] of ≥ 1.7; ***and***

3. a weighted average of ≥ 6% *soil organic carbon*, and ≥ 4% *soil organic carbon* in all parts; ***and***

4. a combined thickness of ≥ 30 cm with ≤ 10 cm non-fulvic material in between.

Field identification

When dark brown, the fulvic horizon is easily identifiable by its colour and its thickness. Fulvic horizons typically occur in association with pyroclastic deposits. However, they may also be found in layers derived from other materials that satisfy the requirements of the Aluandic qualifier. Distinction between the blackish coloured

[6] See Annex 2.

fulvic and *melanic* horizons is made after determining the melanic index, which requires laboratory analyses.

Gypsic horizon

General description

A gypsic horizon (from Greek *gypsos*, gypsum) is a non-cemented horizon containing accumulations of secondary gypsum ($CaSO_4 \cdot 2H_2O$) in various forms. It may be a surface or a subsurface horizon.

Diagnostic criteria

A gypsic horizon consists of *mineral* material and:

1. has ≥ 5% (by mass) gypsum in the fine earth fraction; ***and***

2. has one or both of the following:

    a. ≥ 1% (by volume) of visible secondary gypsum; ***or***

    b. a gypsum content in the fine earth fraction of ≥ 5% higher (absolute, by mass) than that of an underlying layer and no *lithic discontinuity* between the two layers; ***and***

3. has a product of thickness (in centimetres) times gypsum content (percentage, by mass) of ≥ 150; ***and***

4. does not form part of a *petrogypsic* horizon; ***and***

5. has a thickness of ≥ 15 cm.

Field identification

Gypsum occurs as pseudomycelia, as coarse crystals, as nests, beards or coatings, as elongated groupings of fibrous crystals, or as powdery accumulations. The last form gives the gypsic horizon a massive structure. The distinction between compact powdery accumulations and the others is important in terms of soil capability.

Gypsum crystals may be visually mistaken for quartz. Gypsum is soft and can easily be ripped with a knife or broken between thumbnail and forefinger. Quartz is hard and cannot be broken except by hammering.

Additional characteristics

Thin section analysis is helpful to establish the presence of a gypsic horizon and the distribution of the gypsum in the soil mass.

If the accumulation of gypsum becomes such that all or most of the soil and/or rock structure disappears and continuous concentrations of gypsum prevail, the Hypergypsic qualifier is used.

Relationships with some other diagnostics

When gypsic horizons become indurated, transition takes place to the *petrogypsic* horizon, the expression of which may be as massive or platy structures. A gypsic horizon and a *petrogypsic* horizon may overlie each other. *Gypsiric* material contains primary gypsum and no or very little secondary gypsum.

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

Histic horizon

General description

A histic horizon (from Greek *histos*, tissue) is a surface horizon, or a subsurface horizon occurring at a shallow depth, that consists of poorly aerated *organic* material.

Diagnostic criteria

A histic horizon consists of *organic* material and:

1. is saturated with water for ≥ 30 consecutive days in most years or is drained; ***and***

2. has a thickness of ≥ 10 cm

Relationships with some other diagnostics

Histic horizons have similar characteristics to the *folic* horizon; however the *folic* horizon is saturated with water for less than one month 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.

Hortic horizon

General description

A hortic horizon (from Latin *hortus*, garden) is a mineral surface horizon created by the human activities of deep cultivation, intensive fertilization and/or long-continued application of human and animal wastes and other organic residues (e.g. manures, kitchen refuse, compost and night soil).

Diagnostic criteria

A hortic horizon is a surface horizon consisting of *mineral* material and has:

1. a Munsell colour value and chroma of ≤ 3, moist; ***and***

2. a weighted average of ≥ 1% *soil organic carbon*; ***and***

3. a 0.5 *M* $NaHCO_3$ extractable P_2O_5 content[7] of ≥ 100 mg kg^{-1} fine earth in the upper 25 cm; ***and***

4. a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 50%; ***and***

5. ≥ 25% (by volume, by weighted average) of animal pores, coprolites or other traces of soil animal activity; ***and***

6. a thickness of ≥ 20 cm.

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[7] Known as the Olsen routine method (Olsen *et al*., 1954); data according to Gong *et al*., 1997.

Field identification

The hortic horizon is thoroughly mixed. Potsherds and other artefacts are common, although often abraded. Tillage marks or evidence of mixing of the soil can be present.

Relationships with some other diagnostics

Hortic horizons may also fulfil the diagnostic criteria of a *mollic* or *chernic* horizon.

Hydragric horizon

General description

A hydragric horizon (from Greek *hydor*, water, and Latin *ager*, field) is a subsurface horizon that results from human activity associated with wet cultivation.

Diagnostic criteria

A hydragric horizon consists of *mineral* material, is associated with wet cultivation and:

1. is overlain by an *anthraquic* horizon; ***and***

2. consists of one or more subhorizons and each of them has one or more of the following:

   a. Fe or Mn coatings in ≥ 15% of the exposed area, predominantly around root channels and at or near the surfaces of the soil aggregates; ***or***

   b. redox depletions with a Munsell colour value of ≥ 4 and a chroma of ≤ 2, both moist, in macropores; ***or***

   c. Fe or Mn concentrations in ≥ 5% of the exposed area, predominantly inside the soil aggregates; ***or***

   d. Fe_{dith} ≥ 1.5 times and/or Mn_{dith} ≥ 3 times than that of the surface horizon; ***and***

3. has a thickness of ≥ 10 cm.

Field identification

The hydragric horizon occurs below the plough pan of an *anthraquic* horizon. It has reduction features in pores, such as coatings or halos with a Munsell colour hue of 2.5 Y or yellower and a chroma of ≤ 2, both moist, and/or concentrations of Fe and/or Mn in the matrix as a result of the oxidative environment. It usually shows grey clay-fine silt and clay-silt-humus cutans on soil aggregate faces. The features listed as part of diagnostic criterion 2 rarely occur all together in the same layer but are commonly distributed over several subhorizons.

Additional characteristics

Reduced manganese and/or iron move down slowly through the plough pan of the overlying *anthraquic* horizon into the hydragric horizon; the mangenese tending to move further than the iron. Within the hydragric horizon, manganese and iron migrate further into the interiors of the soil aggregates where they are oxidized.

Irragric horizon

General description

An irragric horizon (from Latin *irrigare*, to irrigate, and *ager*, field) is a mineral surface horizon that results from human activity and that builds up gradually through continuous application of irrigation water with substantial amounts of sediments; and which may include fertilizers, soluble salts, organic matter, etc.

Diagnostic criteria

An irragric horizon is a surface horizon consisting of *mineral* material and has:

1. a uniformly structured surface layer; ***and***
2. a higher clay content, particularly fine clay, than the underlying original soil; ***and***
3. differences in medium sand contents, fine sand contents, very fine sand contents, silt contents, clay contents and carbonate contents of < 20% (relative) ***or*** < 4% (absolute) between parts of the horizon; ***and***
4. a weighted average of ≥ 0.5% *soil organic carbon*, decreasing with depth but remaining at ≥ 0.3% at the lower limit of the irragric horizon; ***and***
5. ≥ 25% (by volume, by weighted average) of animal pores, coprolites or other traces of soil animal activity; ***and***
6. a thickness of ≥ 20 cm.

Field identification

Soils with an irragric horizon show evidence of surface raising, which may be inferred from either field observations or from historical records. The irragric horizon shows evidence of considerable biological activity. The lower boundary is clear; and irrigation deposits or buried soils may be present below.

Relationships with some other diagnostics

Irragric horizons differ from *fluvic* materials in that, due to continuous ploughing, they lack evidence of stratification. Some irragric horizons may also qualify as *mollic* or *umbric* horizons, depending on their base saturation.

Melanic horizon

General description

A melanic horizon (from Greek *melas*, black) is a thick, black horizon at or near the soil surface, which is typically associated with short-range-order minerals (commonly allophane) or with organo-aluminium complexes. It has a low bulk density and contains highly humified organic matter that shows a lower ratio of fulvic acids to humic acids compared with the *fulvic* horizon.

Diagnostic criteria

A melanic horizon has:

1. *andic* properties; ***and***
2. a Munsell colour value and chroma of ≤ 2, moist; ***and***

3. a melanic index[8] of < 1.7; ***and***

4. a weighted average of ≥ 6% *soil organic carbon*, and ≥ 4% *soil organic carbon* in all parts; ***and***

5. a combined thickness of ≥ 30 cm with ≤ 10 cm non-melanic material in between.

Field identification

The intense black colour, its thickness, as well as its common association with pyroclastic deposits help to recognize the melanic horizon in the field. However, laboratory analyses to determine the type of organic matter are necessary to identify the melanic horizon unambiguously.

Mollic horizon

General description

A mollic horizon (from Latin *mollis*, soft) is a relatively thick, dark-coloured surface horizon with a high base saturation and a moderate to high content of organic matter.

Diagnostic criteria

A mollic horizon is a surface horizon consisting of *mineral* material. For diagnostic criteria 2 to 4, the weighted average of each value is calculated and then checked against the diagnostic criteria, either for the upper 20 cm, or for the entire mineral soil above *continuous rock*, *technic hard* material or a *cryic*, *petrocalcic*, *petroduric*, *petrogypsic* or *petroplinthic* horizon if starting < 20 cm from the mineral soil surface. If the mollic horizon has subhorizons that start ≥ 20 cm from the mineral soil surface, a weighted average for those subhorizons is not calculated; each value is checked separately against the diagnostic criteria. A mollic horizon has:

1. a soil structure sufficiently strong that it is not both massive and hard or very hard when dry (prisms larger than 30 cm in diameter are included in the meaning of massive if there is no structure further subdividing the prisms); ***and***

2. ≥ 0.6% *soil organic carbon*; ***and***

3. one or both of the following:

   a. in slightly crushed samples a Munsell colour value of ≤ 3 moist, and ≤ 5 dry, and a chroma of ≤ 3 moist; ***or***

   b. all of the following:

      i. ≥ 40% (by mass) calcium carbonate equivalent in the fine earth fraction and/or a texture class of loamy sand or coarser; ***and***

      ii. in slightly crushed samples a Munsell colour a value of ≤ 5 and a chroma of ≤ 3, both moist; ***and***

      iii. ≥ 2.5% *soil organic carbon*; ***and***

[8] See Annex 2.

4. ≥ 0.6% (absolute) more *soil organic carbon* than the parent material, if parent material is present, that has a Munsell colour value of ≤ 4, moist; ***and***

5. a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 50% on a weighted average, throughout the entire thickness of the horizon; ***and***

6. a thickness of one of the following:

   a. ≥ 10 cm if directly overlying *continuous rock*, *technic hard* material or a *cryic, petrocalcic, petroduric, petrogypsic* or *petroplinthic* horizon; ***or***

   b. ≥ 20 cm.

Field identification
A mollic horizon may easily be identified by its dark colour, caused by the accumulation of organic matter, in most cases a well-developed structure (usually a granular or fine subangular blocky structure), an indication of high base saturation (e.g. $pH_{water} > 6$), and its thickness.

Relationships with some other diagnostics
The base saturation of ≥ 50% separates the mollic horizon from the *umbric* horizon, which is otherwise similar. The upper limit of the content of *soil organic carbon* is 20%, which is the lower limit for *organic* material.

A special type of mollic horizon is the *chernic* horizon. It requires a higher content of *soil organic carbon*, a lower chroma, a better developed soil structure, a minimum content of fine earth and a greater minimum thickness.

Some *hortic*, *irragric*, *pretic* or *terric* horizons may also qualify as mollic horizons.

Natric horizon
General description
A natric horizon (from Arabic *natroon*, salt) is a dense subsurface horizon with a distinctly higher clay content than in the overlying horizon(s). It has a high content of exchangeable Na and in some cases, a relatively high content of exchangeable Mg.

Diagnostic criteria
A natric horizon consists of *mineral* material and:

1. has a texture class of loamy sand or finer and ≥ 8% clay; ***and***

2. one or both of the following:

   a. has an overlying coarser textured horizon with all of the following:

      i. the coarser textured horizon is not separated from the natric horizon by a *lithic discontinuity*; ***and***

      ii. if the coarser textured horizon directly overlies the natric horizon, its lowermost subhorizon does not form part of a plough layer; ***and***

iii. if the coarser textured horizon does not directly overlie the natric horizon, the transitional horizon between the coarser textured horizon and the natric horizon has a thickness of ≤ 15 cm; ***and***

iv. if the coarser textured horizon has < 10% clay in the fine earth fraction, the natric horizon has ≥ 4% (absolute) more clay; ***and***

v. if the coarser textured horizon has ≥ 10 and < 50% clay in the fine earth fraction, the ratio of clay in the natric horizon to that of the coarser textured horizon is ≥ 1.4; ***and***

vi. if the coarser textured horizon has ≥ 50% clay in the fine earth fraction, the natric horizon has ≥ 20% (absolute) more clay; ***or***

b. has evidence of illuvial clay in one or more of the following forms:

i. oriented clay bridging ≥ 5% of the sand grains; ***or***

ii. clay coatings lining ≥ 5% of the surfaces in pores; ***or***

iii. clay coatings covering ≥ 5% of the vertical and ≥ 5% of the horizontal surfaces of soil aggregates; ***or***

iv. in thin sections, oriented clay bodies that constitute ≥ 1% of the section; ***or***

v. a COLE of ≥ 0.04 and a ratio of fine clay[9] to total clay in the natric horizon greater by ≥ 1.2 times than the ratio in the overlying coarser textured horizon; ***and***

3. has one or more of the following:

a. a columnar or prismatic structure in some part of the horizon; ***or***

b. both of the following:

i. a blocky structure; ***and***

ii. penetrations of an overlying coarser textured horizon in which there are uncoated silt or sand grains, extending ≥ 2.5 cm into the natric horizon; ***and***

4. has one of the following:

a. an exchangeable Na percentage (ESP[10]) of ≥ 15 throughout the entire natric horizon or its upper 40 cm, whichever is thinner; ***or***

b. both of the following,

i. more exchangeable Mg plus Na than Ca plus exchange acidity (at

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9 Fine clay: < 0.2 µm equivalent diameter.

10 ESP = exchangeable Na × 100/CEC (at pH 7).

pH 8.2) throughout the entire natric horizon or its upper 40 cm, whichever is thinner; ***and***

ii. an exchangeable Na percentage (ESP) of ≥ 15 in some subhorizon starting ≤ 50 cm below the upper limit of the natric horizon; ***and***

5. has a thickness of one-tenth or more of the thickness of the overlying *mineral* material, if present, and one of the following:

   a. ≥ 7.5 cm (combined thickness if composed of lamellae) if the natric horizon has a texture class of sandy loam or finer; ***or***

   b. ≥ 15 cm (combined thickness if composed of lamellae).

Field identification

The colour of the natric horizon ranges from brown to black, especially in the upper part, but lighter colours or yellow to red colours may also be found. The structure is usually coarse columnar or coarse prismatic, sometimes blocky. Rounded tops of the structural elements are characteristic. In many cases, they are covered by a whitish powder coming from the overlying eluvial horizon.

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 coatings occur, especially in the upper part of the horizon. Many natric horizons have poor soil aggregate stability and very low permeability under wet conditions. When dry, the natric horizon is hard to extremely hard. Soil reaction is commonly strongly alkaline with $pH_{water} \geq 8.5$.

Additional characteristics

Another measure to characterize the natric horizon is the sodium adsorption ratio (SAR), which has to be ≥ 13. The SAR is calculated from soil solution data (Na^+, Ca^{2+}, Mg^{2+} given in $mmol_c$/litre): $SAR = Na^+/[(Ca^{2+} + Mg^{2+})/2]^{0.5}$.

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 diagnostics

The surface horizon may be rich in organic matter, have a thickness from a few centimetres to > 25 cm and may be a *mollic* or *chernic* horizon. *Albic* material 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 then becomes saline as well. Salts present may be chlorides, sulfates or carbonates/bicarbonates.

The humus-illuvial part of a natric horizon has a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 50%, which separates it from the *sombric* horizon.

Nitic horizon

General description

A nitic horizon (from Latin *nitidus*, shiny) is a clay-rich subsurface horizon. It has moderately to strongly developed blocky structure breaking to polyhedral, flat-edged or nutty elements with many shiny soil aggregate faces, which cannot or can only partially be attributed to clay illuviation.

Diagnostic criteria

A nitic horizon consists of *mineral* material and:

1. has both of the following:
   a. ≥ 30% clay; ***and***
   b. a silt to clay ratio < 0.4; ***and***
2. has < 20% difference (relative) in clay content over 15 cm to layers directly above and below; ***and***
3. has moderate to strong blocky structure breaking into polyhedral or flat-edged or nut-shaped elements with, in moist state, shiny soil aggregate faces. The shiny faces are not, or are only partially, associated with clay coatings; ***and***
4. has all of the following:
   a. ≥ 4% Fe_{dith} (*free* iron) in the fine earth fraction; ***and***
   b. ≥ 0.2% Fe_{ox} (*active* iron) in the fine earth fraction; ***and***
   c. a ratio between *active* and *free* iron of ≥ 0.05; ***and***
5. does not form part of a *plinthic* horizon; ***and***
6. has a thickness of ≥ 30 cm.

Field identification

A nitic horizon has a texture class of clay loam or finer but may feel loamy. The difference in clay content with the overlying and underlying horizons is gradual or diffuse. Similarly, there is no abrupt colour difference with the horizons directly above and below. The colours are of low value with hues often 2.5YR, moist, but sometimes redder or yellower. The structure is moderate to strong blocky, breaking into polyhedral or flat-edged or nut-shaped elements showing shiny faces.

Additional characteristics

In many nitic horizons, the CEC (by 1 *M* NH_4OAc, pH 7) is < 36 $cmol_c$ kg^{-1} clay, or even < 24 $cmol_c$ kg^{-1} clay. The sum of exchangeable bases (by 1 *M* NH_4OAc, pH 7) plus exchangeable Al (by 1 *M* KCl, unbuffered) is about half of the CEC. The moderate to low CEC reflects the dominance of 1:1 lattice clays (either kaolinite and/or [meta-]halloysite). Many nitic horizons have a ratio of water-dispersible clay total clay of < 0.1.

Relationships with some other diagnostics

The nitic horizon may be considered as a strongly expressed *cambic* horizon with specific properties such as a high amount of active iron. Nitic horizons may show clay coatings and may satisfy the requirements of an *argic* horizon, although the clay content in the nitic horizon is not much higher than in the overlying horizon. Its mineralogy (kaolinitic/[meta]halloysitic) sets it apart from most *vertic* horizons, which have a dominantly smectitic mineralogy. However, nitic horizons may grade laterally into *vertic* horizons in lower landscape positions. The well-expressed soil structure, the high amount of active iron, in some cases, the intermediate CEC in nitic horizons set them apart from *ferralic* horizons. Nitic horizons in cool and moist, freely drained soils of high plateaus and mountains in tropical and subtropical regions may occur in association with *sombric* horizons.

Petrocalcic horizon

General description

A petrocalcic horizon (from Greek *petros*, rock, and Latin *calx*, lime) is an indurated horizon that is cemented by calcium carbonate and in some places, by magnesium carbonate as well. It is either massive or platy in nature and extremely hard.

Diagnostic criteria

A petrocalcic horizon consists of *mineral* material and:

1. has very strong effervescence after adding a 1 *M* HCl solution; ***and***

2. shows induration or cementation, at least partially by secondary carbonates, to the extent that air-dry fragments do not slake in water; ***and***

3. is continuous to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume); ***and***

4. cannot be penetrated by roots except, if present, along the vertical fractures; ***and***

5. has an extremely hard consistence when dry, so that it cannot be penetrated by spade or auger; ***and***

6. has a thickness of ≥ 10 cm or ≥ 1 cm if it is laminar and rests directly on *continuous rock*.

Field identification

Petrocalcic horizons occur as non-platy calcrete (either massive or nodular) or as platy calcrete, of which the following types are the most common:

- *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, grey or pink in colour. They are generally more cemented than the lamellar calcrete and 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 diagnostics

In arid regions, petrocalcic horizons may occur in association with *(petro-)duric* horizons, into which they may grade laterally. The cementing agent differentiates petrocalcic and *duric* horizons. In petrocalcic horizons, calcium and some magnesium carbonate constitute 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* or *petrogypsic* horizons.

Horizons with a significant accumuation of secondary carbonates without induration or cementation qualify as *calcic* horizons.

Petroduric horizon

General description

A petroduric horizon (from Greek *petros*, rock, and Latin *durus*, hard), also known as duripan or dorbank (South Africa), is a subsurface horizon, usually reddish or reddish brown in colour, that 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 a supplementary cementing agent.

Diagnostic criteria

A petroduric horizon consists of *mineral* material and:

1. has induration or cementation in ≥ 50% (by volume) of some subhorizon; ***and***

2. shows 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. when air-dry, < 50% (by volume) slake in 1 *M* HCl even after prolonged soaking, but > 50% slake in concentrated KOH, concentrated NaOH or in alternating acid and alkali; ***and***

4. is continuous to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume); ***and***

5. cannot be penetrated by roots in the indurated or cemented parts except, if present, along the vertical fractures; ***and***

6. has a thickness of ≥ 1 cm.

Field identification

A petroduric horizon has a very firm to extremely firm consistence when moist and is extremely hard when dry. Effervescence after applying 1 *M* HCl may take place, but is probably not as vigorous as in *petrocalcic* horizons, which appear similar.

Relationships with some other diagnostics

In dry and arid climates, petroduric horizons may occur in association with *petrocalcic* horizons, into which they may grade laterally, and/or occur in conjunction with *calcic* or *gypsic* horizons.

Petrogypsic horizon

General description

A petrogypsic horizon (from Greek *petros*, rock, and *gypsos*. gypsum) is a cemented horizon containing accumulations of secondary gypsum ($CaSO_4 \cdot 2H_2O$).

Diagnostic criteria

A petrogypsic horizon consists of *mineral* material and:

1. has ≥ 5% (by mass) gypsum; ***and***
2. has ≥ 1% (by volume) visible secondary gypsum; ***and***
3. shows induration or cementation, at least partially by secondary gypsum, to the extent that air-dry fragments do not slake in water; ***and***
4. is continuous to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume); ***and***
5. cannot be penetrated by roots except, if present, along the vertical fractures; ***and***
6. has a thickness of ≥ 10 cm.

Field identification

Petrogypsic horizons are hard, whitish and composed predominantly of gypsum. Old petrogypsic horizons may be capped by a thin, laminar layer of newly precipitated gypsum about 1 cm thick.

Additional characteristics

Thin section analysis is a helpful technique 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 pores or former pores. Traces of biological activity (pedotubules) are sometimes visible.

Relationships with some other diagnostics

As the petrogypsic horizon develops from a *gypsic* horizon, the two are closely related. Petrogypsic horizons frequently occur in association with *calcic* horizons. Calcic and gypsic accumulations usually occupy different positions in the soil profile because the solubility of calcium carbonate is less than that of gypsum. Normally, they can be distinguished clearly from each other by their morphology (see *calcic* horizon).

Petroplinthic horizon

General description

A petroplinthic horizon (from Greek *petros*, rock, and *plinthos*, brick) is a continuous, fractured or broken layer of indurated material, in which Fe (and in cases also Mn) (hydr-)oxides are an important cement and in which organic matter is either absent or present only in traces.

Diagnostic criteria

A petroplinthic horizon consists of *mineral* material and:

1. is a sheet of connected, strongly cemented to indurated
   a. yellowish, reddish and/or blackish concretions and/or nodules; ***or***
   b. yellowish, reddish and/or blackish concentrations in platy, polygonal or reticulate patterns; ***and***
2. has a penetration resistance[11] of ≥ 4.5 MPa in ≥ 50% of the volume of the fine earth; ***and***
3. has one or both of the following:
   a. ≥ 2.5% (by mass) Fe_{dith} in the fine earth fraction; ***or***
   b. ≥ 10% (by mass) Fe_{dith} in the concretions, nodules and/or concentrations; ***and***
4. has a ratio between Fe_{ox} and Fe_{dith} of < 0.1[12] in the fine earth fraction; ***and***
5. is continuous to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume); ***and***
6. has a thickness of ≥ 10 cm.

Field identification

Petroplinthic horizons are extremely hard and typically rusty brown to yellowish brown. They are either massive or show an interconnected nodular or a reticulate, platy or columnar pattern that encloses non-indurated material. They may be fractured. Roots are generally found only in vertical fractures.

Relationships with some other diagnostics

Petroplinthic horizons are closely associated with *plinthic* and *pisoplinthic* horizons from which they develop. In some places, *plinthic* horizons can be traced by following petroplinthic layers that have formed, for example, in road cuts.

The low ratio between Fe_{ox} and Fe_{dith} separates the petroplinthic horizon from thin iron pans, bog iron and indurated *spodic* horizons as occurring for example in *Podzols*, which in addition contain a fair amount of organic matter.

Pisoplinthic horizon

General description

A pisoplinthic horizon (from Latin *pisum*, pea, and Greek *plinthos*, brick) contains concretions or nodules that are strongly cemented to indurated with Fe (and in some cases also with Mn) (hydr-)oxides.

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11 Asiamah (2000). From this point onwards, the horizon will start hardening irreversibly.

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

Diagnostic criteria

A pisoplinthic horizon consists of *mineral* material and:

1. has ≥ 40% of the volume occupied by strongly cemented to indurated, yellowish, reddish and/or blackish concretions and/or nodules with a diameter of ≥ 2 mm; ***and***
2. does not form part of a *petroplinthic* horizon; ***and***
3. has a thickness of ≥ 15 cm.

Relationships with some other diagnostics

A pisoplinthic horizon results if a *plinthic* horizon hardens in the form of discrete concretions or nodules. The hardness of and the amount of concretions or nodules separate it from the *ferric* horizon. If the concretions or nodules are sufficiently interconnected, the pisoplinthic horizon becomes a *petroplinthic* horizon.

Plaggic horizon

General description

A plaggic horizon (from Low German *plaggen*, sod) is a black or brown mineral surface horizon that results from human activity. Mostly in nutrient-poor soils in the north-western part of Central Europe from Medieval times until the introduction of mineral fertilizers at the beginning of the 20th century, sod and other topsoil materials were commonly used for bedding livestock. The sods consist of grassy, herbaceous or dwarf-shrub vegetation, its root mats and soil material sticking to them. The mixture of sods and excrements was later spread on fields. The material brought in eventually produced an appreciably thickened horizon (in places > 100 cm thick) that is rich in *soil organic carbon*. Base saturation is typically low.

Diagnostic criteria

A plaggic horizon is a surface horizon consisting of *mineral* material and:

1. has a texture class of sand, loamy sand, sandy loam or loam, or a combination of them; ***and***
2. contains *artefacts*; ***and***
3. has a Munsell colour with a value of ≤ 4 moist, and ≤ 5 dry, and a chroma of ≤ 4 moist; ***and***
4. has ≥ 0.6% *soil organic carbon*; ***and***
5. has a base saturation (by 1 *M* NH_4OAc, pH 7) of < 50%, unless the soil has been limed or fertilized; ***and***
6. occurs in locally raised land surfaces; ***and***
7. has a thickness of ≥ 20 cm.

Field identification

The plaggic horizon has brownish or blackish colours, related to the origin of source materials. It contains *artefacts*, but normally less than 20%. Its reaction is mostly slightly to strongly acid. The pH may have risen due to recent liming but without reaching a high base saturation. It shows evidence of old agricultural operations in its lower part, such as spade or hook marks as well as old cultivation layers. Plaggic horizons commonly overlie buried soils although the original surface layers may be mixed with the plaggen. In some cases, ditches had been made in the buried soil as a cultivation mode for soil improvement. The lower boundary is typically clear.

Additional characteristics

The texture class is in most cases sand or loamy sand. Sandy loam and loam are rare. The *soil organic carbon* may include carbon added with the plaggen. The P_2O_5 content (extractable in 1percent citric acid) in plaggic horizons may be high, often ≥ 0.025% within ≤ 20 cm of the soil surface. Originally, the plaggic horizon has a low base saturation. If limed or fertilized, this criterion is waived.

Relationships with some other diagnostics

The low base saturation sets the plaggic horizon apart from the *terric* horizon. Few other soil characteristics differentiate the *terric* and plaggic horizons from each other. *Terric* horizons usually have a neutral to slightly alkaline soil reaction (pH_{water} is normally ≥ 7) and may contain free calcium carbonates. They usually have a high biological activity. Some plaggic horizons may also qualify as *umbric* or even as *mollic* horizon. It cannot be excluded that a plaggic horizon fulfils also the criteria of the *pretic* horizon. In this case, the soil scientist should use historical knowledge for making the final decision, whether the horizon is called plaggic or *pretic*.

Plinthic horizon

General description

A plinthic horizon (from Greek *plinthos*, brick) is a subsurface horizon that is rich in Fe (in some cases also Mn) (hydr-)oxides and poor in humus. The clay is mostly kaolinitic, with the presence of other products of strong weathering, such as gibbsite. The plinthic horizon usually changes irreversibly to a layer of hard concretions or nodules or a hardpan on exposure to repeated wetting and drying with free access to oxygen.

Diagnostic criteria

A plinthic horizon consists of *mineral* material and:

1. has within ≥ 15% of the volume, single or in combination:

    a. discrete concretions and/or nodules that in the moist state are at least firm, with a redder hue or stronger chroma than the surrounding material; ***or***

    b. concentrations in platy, polygonal or reticulate patterns that in the moist state are at least firm, with a redder hue or stronger chroma than the surrounding material; ***and***

2. one or more of the following:

    a. has ≥ 2.5% (by mass) Fe_{dith} in the fine earth fraction; ***or***

    b. has ≥ 10% (by mass) Fe_{dith} in the concretions, nodules or concentrations; ***or***

    c. hardens irreversibly after repeated wetting and drying; ***and***

3. has a ratio between Fe_{ox} and Fe_{dith} of < 0.1 in the fine earth fraction[13]; ***and***

4. does not form part of a *petroplinthic* or *pisoplinthic* horizon; ***and***

5. has a thickness of ≥ 15 cm.

Field identification
A plinthic horizon shows prominent concretions or nodules or concentrations in platy, polygonal or reticulate patterns. In a perennially moist soil, many concretions, nodules or concentrations are not hard but firm or very firm and can be cut with a spade. Repeated wetting and drying will generally change them irreversibly to hard concretions or nodules or a hardpan (ironstone), especially if also exposed to heat from the sun, but they do not harden irreversibly as a result of a single cycle of drying and rewetting.

Additional characteristics
Micromorphological studies may reveal the extent of impregnation of the soil mass by Fe (hydr-)oxides. The plinthic horizon with concretions or nodules has developed under redoximorphic conditions caused by stagnating water and shows *stagnic* properties. The plinthic horizon with concentrations in platy, polygonal or reticulate patterns has developed under oximorphic conditions in the capillary fringe of groundwater. In this case, the plinthic horizon shows *gleyic* properties with oximorphic colours and is in many cases underlain by a whitish horizon. In many plinthic horizons, prolonged *reducing conditions* are not present any more.

Relationships with some other diagnostics
If the concretions and nodules of the plinthic horizon harden and reach ≥ 40% of the volume, the plinthic horizon becomes a *pisoplinthic* horizon. If it hardens to a continuous sheet, the plinthic horizon becomes a *petroplinthic* horizon.

If the concretions, nodules or mottles do not reach 15% of the volume, it may be a *ferric* horizon.

Pretic horizon
General description
A pretic horizon (from Portuguese preto, black) is a mineral surface horizon that results from human activities including the addition of charcoal. It is characterized by its dark colour, the presence of artefacts (ceramic fragments, lithic instruments, bone or shell tools etc.) and high contents of organic carbon, phosphorus, calcium, magnesium and micronutrients (mainly zinc and manganese), usually contrasting with natural soils in the surrounding area. It typically contains visible remnants of charcoal.

Pretic horizons are for example widespread in the Amazon Basin, where they are the result of pre-Columbian activities and have persisted over many centuries despite the prevailing humid tropical conditions and high organic matter mineralization rates. These soils with a pretic horizon are known as ‘Terra Preta de Indio’ or ‘Amazonian Dark Earths’. They generally have high organic carbon stocks. Many of them are dominated by low-activity clays.

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

Diagnostic criteria

A pretic horizon is a surface horizon consisting of *mineral* material and has:

1. a Munsell colour value of ≤ 4 and a chroma of ≤ 3, both moist; ***and***
2. ≥ 1% organic carbon; ***and***
3. exchangeable Ca plus Mg (by 1 *M* NH_4OAc, pH 7) of ≥ 2 $cmol_c$ kg^{-1} fine earth; ***and***
4. ≥ 30 mg kg^{-1} of extractable P (Mehlich-1); ***and***
5. one or more of the following:
   a. ≥ 1% *artefacts* (by volume, by weighted average); ***or***
   b. ≥ 1% charcoal (by volume, by weighted average); ***or***
   c. evidences of past human occupation in the surrounding landscape, e.g. constructions, gardens, shell mounds ('sambaquis'), or earthworks (geoglyphs); ***and***
6. < 25% (by volume, by weighted average) of animal pores, coprolites or other traces of soil animal activity; ***and***
7. one or more layers with a combined thickness of ≥ 20 cm.

Additional characteristics

Charcoal is an *artefact* only if it is intentionally manufactured by humans.

Relationships with some other diagnostics

Pretic horizons do not show the animal activity required for *hortic* and *irragric* horizons. The diagnostic criteria for P concentrations in pretic and *hortic* horizons are based on different analytical methods with a lower requirement for the pretic horizon. It cannot be excluded that a pretic horizon fulfils also the criteria of the *plaggic* horizon. In this case, the soil scientist should use historical knowledge for making the final decision, whether the horizon is called *plaggic* or pretic. Some pretic horizons may qualify as *mollic* or *umbric* horizons.

Protovertic horizon

General description

A protovertic horizon (from Greek *protou*, before, and Latin *vertere,* to turn) has swelling and shrinking clays.

Diagnostic criteria

A protovertic horizon consists of *mineral* material and has:

1. ≥ 30% clay; ***and***
2. one or more of the following:

   a. wedge-shaped soil aggregates in ≥ 10% of the soil volume; ***or***

   b. slickensides (pressure faces with smooth striations or grooves that are produced by shrink-swell forces) at ≥ 5% of the surfaces of soil aggregates; ***or***

   c. shrink-swell cracks; ***or***

   d. a COLE of ≥ 0.06 averaged over the depth of the horizon; ***and***

3. a thickness of ≥ 15 cm.

Field identification
Wedge-shaped aggregates and slickensides may not be immediately evident if the soil is moist. A decision about their presence can sometimes only be made after the soil has dried out. Wedge-shaped aggregates may be a substructure of larger angular blocky or prismatic elements, which should be carefully examined to see if wedge-shaped aggregates are present.

Relationships with some other diagnostics
If the swelling and shrinking is more prominent (or the layer is thicker) the protovertic horizon grades into a *vertic* horizon.

Salic horizon
General description
A salic horizon (from Latin *sal*, salt) is a surface horizon or a subsurface horizon at a shallow depth that contains high amounts of readily soluble salts, i.e. salts more soluble than gypsum ($CaSO_4 \cdot 2H_2O$; log Ks = -4.85 at 25 °C).

Diagnostic criteria
A salic horizon has:

1. at some time of the year an electrical conductivity of the saturation extract (EC_e) at 25 °C of

   a. ≥ 15 dS m^{-1}; ***or***

   b. ≥ 8 dS m^{-1} if the pH_{water} of the saturation extract is ≥ 8.5; ***and***

2. at some time of the year a product of thickness (in centimetres) and EC_e at 25 °C (in dS m^{-1}) of ≥ 450; ***and***

3. a thickness of ≥ 15 cm.

Field identification
Salicornia, Tamarix or other halophyte plants and salt-tolerant crops are first indicators. Salt-affected layers are often puffy. Salts precipitate only after evaporation of most soil moisture; if the soil is moist, salt may not be visible.

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

Additional characteristics

In alkaline carbonate soils, an EC_e at 25 °C of ≥ 8 dS m^{-1} and a pH_{water} of ≥ 8.5 are very common. Salic horizons may consist of *organic* or *mineral* material.

Sombric horizon

General description

A sombric horizon (from French *sombre*, dark) is a dark-coloured subsurface horizon containing illuvial humus that is neither associated with Al nor dispersed by Na.

Diagnostic criteria

A sombric horizon consists of *mineral* material and:

1. has a lower Munsell colour value or chroma, moist, than the overlying horizon; ***and***

2. shows evidence of humus accumulation by one or more of the following:

   a. a higher content of *soil organic carbon* with respect to the directly overlying horizon; ***or***

   b. illuvial humus on soil aggregate surfaces or in pores; ***or***

   c. illuvial humus in pores visible in thin sections; ***and***

3. does not have a *lithic discontinuity* at its upper limit, does not directly underlie a layer with *albic* material and does not form part of a *natric* or *spodic* horizon; ***and***

4. has a thickness of ≥ 15 cm.

Field identification

Sombric horizons are found in dark-coloured subsoils, associated with cool and moist, well-drained soils of high plateaus and mountains in tropical and subtropical regions. They resemble buried horizons but, in contrast to many of these, sombric horizons more or less follow the shape of the surface.

Relationships with some other diagnostics

Sombric horizons may coincide with *argic*, *cambic*, *ferralic* or *nitic* horizons. Sombric horizons may resemble *melanic* and *fulvic* or buried *mollic* or *umbric* horizons. *Spodic* horizons are differentiated from sombric horizons by their much higher CEC of the clay fraction. The humus-illuvial part of *natric* horizons has a higher clay content, a high Na saturation and a specific structure, which separates them from sombric horizons.

Spodic horizon

General description

A spodic horizon (from Greek *spodos*, wood ash) is a subsurface horizon that contains illuvial substances composed of organic matter and Al, or of illuvial Fe. The illuvial materials are characterized by a high pH-dependent charge, a relatively large surface area and high water retention.

Diagnostic criteria

A spodic horizon consists of *mineral* material and:

1. has a pH (1:1 in water) of < 5.9 in ≥ 85% of the horizon, unless the soil is cultivated; ***and***

2. has in ≥ 85% of its uppermost 1 cm, one or both of the following:

   a. ≥ 0.5% *soil organic carbon*; ***or***

   b. an optical density of the oxalate extract (ODOE) value of ≥ 0.25; ***and***

3. one or both of the following:

   a. is overlain by *albic* material, that is not separated from the spodic horizon by a *lithic discontinuity* and that overlies the spodic horizon either directly or above a transitional horizon that has a thickness of one-tenth or less of the overlying *albic* material, ***and***

      has in ≥ 85% of its uppermost 2.5 cm, one of the following Munsell colours, moist (crushed and smoothed sample):

      i. a hue of 5YR or redder; ***or***

      ii. a hue of 7.5YR and a value of ≤ 5 and a chroma of ≤ 4; ***or***

      iii. a hue of 10YR and a value and a chroma of ≤ 2; ***or***

      iv. a colour of 10YR 3/1; ***or***

      v. a hue of N and a value of ≤ 2; ***or***

   b. has one of the colours listed above or a colour with a hue of 7.5YR, a value of ≤ 5 and a chroma of 5 or 6, all moist (crushed and smoothed sample), in ≥ 85% of its uppermost 2.5 cm, ***and***

      has one or more of the following:

      i. cementation by organic matter and Al with or without Fe, in ≥ 50% of the horizon and a very firm or firmer consistency in the cemented part; ***or***

      ii. ≥ 10% of the sand grains of the horizon showing cracked coatings; ***or***

      iii. a subhorizon with an Al_{ox} + ½Fe_{ox} value of ≥ 0.5% that is ≥ 2 times higher than the lowest Al_{ox} + ½Fe_{ox} value of all the mineral horizons above the spodic horizon; ***or***

      iv. a subhorizon with an ODOE value of ≥ 0.25 that is ≥ 2 times higher than the lowest ODOE value of all the mineral horizons above the spodic horizon; ***or***

v. ≥ 10% (by volume) Fe lamellae[14] in a layer ≥ 25 cm thick; ***and***

4. does not form part of a *natric* horizon; ***and***

5. if occurring under *tephric* material that satisfies the requirements of *albic* material: has a C_{py}/OC[15] and a C_f/C_{py} of ≥ 0.5 in its uppermost 2.5 cm; ***and***

6. has a thickness of ≥ 2.5 cm and its lower limit at

   a. the lower limit of the lowermost subhorizon fulfilling the diagnostic criteria 1 and 4 and having one of the colours listed under 3; ***or***

   b. the lower limit of the lowermost subhorizon fulfilling the diagnostic criteria 1 and 4 and one or more of the diagnostic criteria listed under 3b, i - v;

   whichever is deeper.

Field identification

A spodic horizon often underlies *albic* material and has brownish-black to reddish-brown colours, which often fade downwards. Spodic horizons can also be characterized by the presence of a thin iron pan, or when weakly developed, by the presence of organic pellets, or by the accumulation of Fe in lamellar form.

Relationships with some other diagnostics

Spodic horizons are often associated with *albic* material, which they underlie; there may be a *hortic*, *plaggic*, *terric* or *umbric* horizon above, with or without *albic* material.

Spodic horizons in volcanic materials may exhibit *andic* properties as well. Spodic horizons in other Podzols may exhibit some characteristics of the *andic* properties, but normally have a higher bulk density. For classification purposes, the presence of a spodic horizon, unless buried deeper than 50 cm, is given preference over the occurrence of *andic* properties.

Some layers with *andic* properties are covered by relatively young, light-coloured volcanic ejecta that satisfy the requirements of *albic* material. Therefore, in a number of cases, analytical tests are needed in order to verify the difference between layers with *andic* properties and spodic horizons, in particular the C_{py} to OC or C_f to C_{py} ratio tests.

Similar to many spodic horizons, *sombric* horizons also contain more organic matter than an overlying layer. They can be differentiated from each other by the clay mineralogy (kaolinite usually dominating in *sombric* horizons, whereas the clay fraction of spodic horizons commonly contains significant amounts of vermiculite and Al-interlayered chlorite) and the much higher CEC of the clay fraction in spodic horizons.

Plinthic horizons, which contain large amounts of accumulated Fe, have less Fe_{ox} than the spodic horizons.

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[14] Iron lamellae are non-cemented bands of illuvial iron < 2.5 cm thick.

[15] C_{py}, C_f and OC are pyrophosphate-extractable C, fulvic acid C and organic C, respectively (Ito *et al.,* 1991), expressed as percent of the fine earth (0–2 mm) fraction on an oven-dried (105 °C) basis.

Terric horizon

General description

A terric horizon (from Latin *terra*, earth) is a mineral surface horizon that develops through addition of, for example, earthy manures, compost, beach sands, loess or mud. It may contain stones, randomly sorted and distributed. In most cases it is built up gradually over a long period of time. Occasionally, terric horizons are created by single additions of material. Normally the added material is mixed with the original topsoil.

Diagnostic criteria

A terric horizon is a surface horizon consisting of *mineral* material and:

1. has a colour related to the source material; ***and***
2. has a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 50%; ***and***
3. does not show stratification; ***and***
4. occurs in locally raised land surfaces; ***and***
5. has a thickness of ≥ 20 cm.

Field identification

Soils with a terric horizon show a raised surface that may be inferred, either from field observation or from historical records. The terric horizon is not homogeneous, but subhorizons are thoroughly mixed. It commonly contains *artefacts* such as pottery fragments, cultural debris and refuse, that are typically very small (< 1 cm in diameter) and much abraded.

Relationships with some other diagnostics

Few soil characteristics differentiate the terric and *plaggic* horizons from each other. Terric horizons commonly show a high biological activity, have a neutral to slightly alkaline soil reaction (pH_{water} is normally ≥ 7), and may contain free lime, whereas *plaggic* horizons have an acid soil reaction, unless lime or mineral fertilizers have raised the pH. The colour of the terric horizon is strongly related to the source material. Buried soils may be observed at the base of the horizon although mixing can obscure the contact. Some terric horizons may qualify as *mollic* horizon.

Thionic horizon

General description

A thionic horizon (from Greek *theion*, sulfur) is an extremely acid subsurface horizon in which sulfuric acid is formed through oxidation of sulfides.

Diagnostic criteria

A thionic horizon has:

1. a pH < 4 (1:1 by mass in water, or in a minimum of water to permit measurement); ***and***
2. one or more of the following:

   a. mottles or coatings with accumulations of iron or aluminium sulfate or hydroxysulfate minerals; ***or***

b. direct superposition on *sulfidic* material; ***or***

c. ≥ 0.05% (by mass) water-soluble sulfate; ***and***

3. a thickness of ≥ 15 cm.

Field identification

Thionic horizons generally exhibit pale yellow jarosite or yellowish-brown schwertmannite mottles or coatings. Soil reaction is extremely acid; pH_{water} of 3.5 is not uncommon. While mostly associated with recent sulfidic coastal sediments, thionic horizons may also develop inland in *sulfidic* materials that may be present either in natural deposits or in *artefacts* such as mine spoil.

Additional characteristics

Iron or aluminium sulfate or hydroxysulfate minerals include jarosite, natrojarosite, schwertmannite, sideronatrite and tamarugite. Thionic horizons may consist of *organic* or *mineral* material.

Relationships with some other diagnostics

A thionic horizon often underlies a strongly mottled horizon with *stagnic* properties (reddish to reddish-brown iron hydroxide mottles and a light-coloured, Fe-depleted matrix).

Umbric horizon

General description

An umbric horizon (from Latin *umbra*, shade) is a relatively thick, dark-coloured surface horizon with a low base saturation and a moderate to high content of organic matter.

Diagnostic criteria

An umbric horizon is a surface horizon consisting of *mineral* material. For diagnostic criteria 2 to 4, the weighted average of each value is calculated and then checked against the diagnostic criteria, either for the upper 20 cm, or for the entire mineral soil above *continuous rock*, *technic hard* material or a *cryic*, *petroduric* or *petroplinthic* horizon if starting < 20 cm from the mineral soil surface. If the umbric horizon has subhorizons that start ≥ 20 cm from the mineral soil surface, a weighted average for those subhorizons is not calculated; each value is checked separately against the diagnostic criteria. An umbric horizon has:

1. a soil structure sufficiently strong, that it is not both massive and hard or very hard, when dry (prisms larger than 30 cm in diameter are included in the meaning of massive if there is no structure further subdividing the prisms); ***and***

2. ≥ 0.6% *soil organic carbon*; ***and***

3. one or both of the following:

   a. in slightly crushed samples a Munsell colour value of ≤ 3 moist, and ≤ 5 dry, and a chroma of ≤ 3 moist; ***or***

   b. all of the following:

i. a texture class of loamy sand or coarser; ***and***

ii. in slightly crushed samples a Munsell colour a value of ≤ 5 and a chroma of ≤ 3, both moist; ***and***

iii. ≥ 2.5% *soil organic carbon*; ***and***

4. ≥ 0.6% (absolute) more *soil organic carbon* than the parent material, if parent material is present, that has a Munsell colour value of ≤ 4, moist; ***and***

5. a base saturation (by 1 *M* NH_4OAc, pH 7) of < 50% on a weighted average, throughout the entire thickness of the horizon; ***and***

6. a thickness of one of the following:

   a. ≥ 10 cm if directly overlying *continuous rock*, *technic hard* material or a *cryic*, *petroduric* or *petroplinthic* horizon; ***or***

   b. ≥ 20 cm.

Field identification

The main field characteristics 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.

Most umbric horizons have an acid reaction (pH_{water} < 5.5), which usually indicates a base saturation of < 50%. An additional indication for the strong acidity is a shallow, horizontal rooting pattern in the absence of a physical barrier.

Relationships with some other diagnostics

The base saturation requirement sets the umbric horizon apart from the *mollic* horizon, which is otherwise very similar. The upper limit of the content of *soil organic carbon* is 20%, which is the lower limit for *organic* material.

Some *irragric* or *plaggic* horizons may also qualify as umbric horizons.

Vertic horizon

General description

A vertic horizon (from Latin *vertere*, to turn) is a clayey subsurface horizon that, as a result of shrinking and swelling, has slickensides and wedge-shaped soil aggregates.

Diagnostic criteria

A vertic horizon consists of *mineral* material and has:

1. ≥ 30% clay; ***and***

2. one or both of the following:

   a. wedge-shaped soil aggregates with a longitudinal axis tilted between ≥ 10° and ≤ 60° from the horizontal in ≥ 20% of the soil volume; ***or***

b. slickensides (pressure faces with smooth striations or grooves that are produced by shrink-swell forces) at ≥ 10% of the surfaces of soil aggregates; ***and***

3. *shrink-swell cracks*; ***and***

4. a thickness of ≥ 25 cm.

Field identification

Vertic horizons are clayey, and when dry often have a hard to very hard consistency. Polished, shiny surfaces (*slickensides*), often at sharp angles, are distinctive.

Wedge-shaped aggregates and slickensides may not be immediately evident if the soil is moist. A decision about their presence can sometimes only be made after the soil has dried out. Wedge-shaped aggregates may be a substructure of larger angular blocky or prismatic elements, which should be carefully examined to see if wedge-shaped aggregates are present.

Additional characteristics

The 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 ≥ 0.06.

Relationships with some other diagnostics

Several other diagnostic horizons may also have high clay contents, e.g. the *argic*, *natric* and *nitic* horizons. Although some of them may qualify as vertic horizons, most of them lack the characteristics typical for the vertic horizon. However, they may be laterally linked in the landscape with the vertic horizon, the latter usually taking up the lowest position. Less pronounced swelling and shrinking of clays leads to a *protovertic* horizon.

DIAGNOSTIC PROPERTIES

Abrupt textural difference

General description

An abrupt textural difference (from Latin *abruptus*, abrupt) is a very sharp increase in clay content within a limited depth range.

Diagnostic criteria

An abrupt textural difference requires:

1. ≥ 8% clay in the underlying layer; ***and***
2. within ≤ 5 cm, one of the following:
   a. at least a doubling of the clay content if the overlying layer has < 20% clay; ***or***
   b. ≥ 20% (absolute) increase in clay content if the overlying layer has ≥ 20% clay.

Albeluvic glossae

General description

The term albeluvic glossae (from Latin *albus*, white, and *eluere*, to wash out, and Greek *glossa*, tongue) is connotative of penetrations of clay- and Fe-depleted material into an *argic* horizon. Albeluvic glossae occur along soil aggregate surfaces forming vertically continuous tongues. In horizontal sections they exhibit a polygonal pattern.

Diagnostic criteria

Albeluvic glossae refer to a combination of stronger coloured parts and lighter coloured parts within the same layer, with all of the following:

1. the stronger coloured parts belong to an *argic* horizon; ***and***
2. the lighter coloured parts consist of *albic* material; ***and***
3. the stronger coloured parts have, compared with the lighter coloured parts, the following Munsell colour, moist:
   a. a hue ≥ 2.5 units redder, ***or***
   b. a value ≥ 1 unit lower, ***or***
   c. a chroma ≥ 1 unit higher; ***and***
4. the clay content of the stronger coloured parts is higher compared with the lighter coloured parts, as specified for the *argic* horizon; ***and***
5. the lighter coloured parts have a greater depth than width, with the following horizontal dimensions:
   a. ≥ 0.5 cm in *argic* horizons that have a clay or silty clay texture class; ***or***

b. ≥ 1 cm in *argic* horizons that have a texture class of silt, silt loam, silty clay loam, loam, clay loam or sandy clay; ***or***

c. ≥ 1.5 cm in *argic* horizons with other texture classes; ***and***

6. the lighter coloured parts start at the upper limit of the *argic* horizon and are continuous to a depth of ≥ 10 cm below the upper limit of the *argic* horizon; ***and***

7. the lighter coloured parts occupy areas ≥ 10 and ≤ 90% in both vertical and horizontal sections, within the upper 10 cm of the *argic* horizon; ***and***

8. do not occur within a plough layer.

Relationships with some other diagnostics

Albeluvic glossae are a special case of *retic* properties. In *retic* properties, the lighter coloured parts may be thinner and are not necessarily vertically continuous. *Retic* properties may also be present in *natric* horizons whereas albeluvic glossae are defined only in *argic* horizons. The *argic* horizon into which the albeluvic glossae penetrate may also fulfil the diagnostic criteria of a *fragic* horizon. The *argic* horizon is overlain by a layer with *albic* material or by a *cambic* horizon or by a plough layer.

Andic properties

General description

Andic properties (from Japanese *an*, dark, and *do*, soil) result from moderate weathering of mainly pyroclastic deposits. The presence of short-range-order minerals and/or organo-metallic complexes is characteristic for andic properties. These minerals and complexes are commonly part of the weathering sequence in pyroclastic deposits (*tephric* soil material → *vitric* properties → andic properties). However, andic properties with organo-metallic complexes may also form in non-pyroclastic silicate-rich materials in cool-temperate and humid climates.

Andic properties may be found at the soil surface or in the subsurface, commonly occurring as layers. Many surface layers with andic properties contain a high amount of organic matter (≥ 5%), are commonly very dark coloured (Munsell colour value and chroma of ≤ 3, moist), have a fluffy macrostructure, and in some places a smeary consistence. They have a low bulk density and commonly have a silt loam or finer texture. Andic surface layers rich in organic matter may be very thick, having a thickness of ≥ 50 cm in some soils. Andic subsurface layers are generally somewhat lighter coloured.

Andic layers may have different characteristics, depending on the type of the 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 liquefied stage and back into the solid condition. In perhumid climates, humus-rich andic layers may contain more than twice the water content of samples that have been oven-dried and rewetted (hydric characteristic).

Two major types of andic properties are recognized: one in which allophane, imogolite and similar minerals are predominant (the *silandic* type); and one in which Al complexed by organic acids prevails (the *aluandic* type). The silandic property typically gives a strongly acid to neutral soil reaction and is a bit lighter coloured, while the aluandic property gives an extremely acid to acid reaction and a blackish colour.

Diagnostic criteria

Andic[16] properties require:

1. an Al_{ox} + ½Fe_{ox} value of ≥ 2%; ***and***

2. a bulk density[17] of ≤ 0.9 kg dm^{-3}; ***and***

3. a phosphate retention of ≥ 85%.

Field identification

Andic properties may be identified using the sodium fluoride field test of Fieldes and Perrott (1966). A pH in NaF of ≥ 9.5 indicates allophane and/or organo-aluminium complexes in carbonate-free soils. The test is indicative for most layers with andic properties, except for those very rich in organic matter. However, the same reaction occurs in *spodic* horizons and in certain acid clays that are rich in Al-interlayered clay minerals.

Additional characteristics

Andic properties may be divided into silandic and aluandic properties. Silandic properties show a Si_{ox} content of ≥ 0.6% or an Al_{py}/Al_{ox} of < 0.5; aluandic properties show a Si_{ox} content of < 0.6% and an Al_{py}/Al_{ox} of ≥ 0.5. Transitional alusilandic properties show a Si_{ox} content between ≥ 0.6 and < 0.9% and an Al_{py}/Al_{ox} between ≥ 0.3 and < 0.5 (Poulenard and Herbillon, 2000) and are regarded as a special case of silandic properties.

Uncultivated, organic matter-rich surface layers with silandic properties typically have a pH_{water} of ≥ 4.5, while uncultivated surface layers with aluandic properties and rich in organic matter typically have a pH_{water} of < 4.5. Generally, pH_{water} in silandic subsoil layers is ≥ 5.

Relationships with some other diagnostics

Vitric properties are distinguished from andic properties by a lesser degree of weathering. This is evidenced by the presence of volcanic glasses and usually by a lower amount of short-range-order pedogenetic minerals and/or organo-metallic complexes, as characterized by a lower amount of Al_{ox} and Fe_{ox}, a higher bulk density, or a lower phosphate retention.

Spodic horizons, which also contain complexes of sesquioxides and organic substances, can exhibit andic properties as well. Andic properties may also be present in *chernic, mollic* or *umbric* horizons.

Anthric properties

General description

Anthric properties (from Greek *anthropos*, human) apply to some cultivated soils with *mollic* or *umbric* horizons. Some of them are altered natural *mollic* or *umbric* horizons. But some of the *mollic* horizons with anthric properties are natural *umbric* horizons transformed into *mollic* horizons by liming and fertilization. Even thin, light-coloured or humus-poor mineral topsoil horizons may be transformed into *umbric* or even

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[16] Adapted after Shoji *et al*., 1996, and Takahashi, Nanzyo and Shoji, 2004.

[17] For bulk density, the volume is determined after an undried soil sample has been desorbed at 33 kPa (no prior drying), and afterwards the weight is determined oven-dried (see Annex 2).

mollic horizons by long-term cultivation (ploughing, liming, fertilization etc.). In this case the soil has very little biological activity, which is especially uncommon for soils with *mollic* horizons.

Diagnostic criteria

Anthric[18] properties:

1. occur in soils with a *mollic* or *umbric* horizon; ***and***

2. show evidence of human disturbance by one or more of the following:

   a. an abrupt lower boundary at ploughing depth and evidence of mixing of humus-richer and humus-poorer soil materials by cultivation; ***or***

   b. lumps of applied lime; ***or***

   c. ≥ 1.5 g kg^{-1} P_2O_5 soluble in 1percent citric acid; ***and***

3. show < 5% (by volume) of animal pores, coprolites or other traces of soil animal activity

   a. in a depth between 20 and 25 cm from the soil surface, if the soil is unploughed; ***or***

   b. in a depth range of 5 cm below the plough layer.

Field identification

Signs of mixing or cultivation, evidence of liming (e.g. remnants of applied lime chunks), the dark colour and the almost complete absence of traces of soil animal activity are the main criteria for recognition.

Incorporated humus-richer material may be established with the naked eye, using a 10x hand lens or using thin sections, depending on the degree of fragmentation/dispersion of the humus-richer material. The incorporated humus-richer material is typically weakly bound to the humus-poorer material, which is manifested by uncoated mineral grains of silt or sand size in a darker matrix throughout the mixed layer.

Relationships with some other diagnostics

Anthric properties are an additional characteristic of some *mollic* or *umbric* horizons. *Chernic* horizons show normally a higher animal activity and do not have anthric porperties.

Aridic properties

General description

The term aridic properties (from Latin *aridus*, dry) combines a number of properties that are common in surface horizons of soils under arid conditions, which can occur under any temperature regime from very hot to very cold, and where pedogenesis exceeds new accumulation at the soil surface by aeolian or alluvial activity.

[18] Modified after Krogh and Greve (1999).

Diagnostic criteria

Aridic properties require:

1. a *soil organic carbon* content, calculated as a weighted average in the upper 20 cm of the soil or down to the top of a diagnostic subsurface horizon, a cemented or indurated layer or to *continuous rock* or *technic hard* material, whichever is shallower; that meets one the following:

   a. < 0.2%; ***or***

   b. < 0.6% if the texture class in the fine earth fraction is sandy loam or finer; ***or***

   c. < 1%, if the soil is periodically flooded or if it has an EC_e at 25 °C of ≥ 4 dS m^{-1} somewhere within ≤ 100 cm of the soil surface; ***and***

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

   a. the sand fraction in some layer in the upper 20 cm of the soil or in in-blown material filling cracks contains rounded or subangular sand particles showing a matt surface (use a ×10 hand lens); these particles make up ≥ 10% of the medium and coarser sand fraction; ***or***

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

   c. aeroturbation (e.g. cross-bedding) in some layer in the upper 20 cm of the soil; ***or***

   d. evidence of wind erosion; ***or***

   e. evidence of wind deposition in some layer in the upper 20 cm of the soil; ***and***

3. broken and crushed samples with a Munsell colour value of ≥ 3 moist, and ≥ 5 dry, and a chroma of ≥ 2 moist in the upper 20 cm of the soil or down to the top of a diagnostic subsurface horizon, a cemented or indurated layer or to *continuous rock* or *technic hard* material, whichever is shallower; ***and***

4. a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 75% in the upper 20 cm of the soil or down to the top of a diagnostic subsurface horizon, a cemented or indurated layer or to *continuous rock* or *technic hard* material, whichever is shallower.

Additional characteristics

The presence of acicular (*needle-shaped*) clay minerals (e.g. sepiolite and palygorskite) in soils is considered connotative of a desert environment, but it has not been reported in all desert soils. This may be due either 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, or that, in some desert environments, there has not been sufficient weathering to produce detectable quantities of secondary clay minerals.

Continuous rock

Diagnostic criteria

Continuous rock is consolidated material underlying the soil, exclusive of cemented or indurated pedogenetic horizons such as *petrocalcic*, *petroduric*, *petrogypsic* and *petroplinthic* horizons. Continuous rock is sufficiently consolidated to remain intact when an air-dried specimen, 25–30 mm on one side, is submerged in water for 1 hour. The material is considered continuous only if cracks into which roots can enter are on average ≥ 10 cm apart and occupy < 20% (by volume) of the continuous rock, with no significant displacement of the rock having taken place.

Geric properties

General description

Geric properties (from Greek *geraios*, old) refer to mineral soil material that has a very low sum of exchangeable bases plus exchangeable Al or even acts as an anion exchanger.

Diagnostic criteria

Geric properties require one or both of the following:

1. a sum of exchangeable bases (by 1 *M* NH_4OAc, pH 7) plus exchangeable Al (by 1 *M* KCl, unbuffered) of < 1.5 $cmol_c$ kg^{-1} clay ***or***
2. a delta pH (pH_{KCl} minus pH_{water}) of ≥ +0.1.

Gleyic properties

General description

Soil materials develop gleyic properties (from Russian *gley*, mucky soil mass) if they are saturated with groundwater (or were saturated in the past, if now 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). However, there may be gleyic properties in a clayic layer over a sandy layer, even without the influence of groundwater. In some soils with gleyic properties, the *reducing conditions* are caused by upmoving gases such as methane or carbon dioxide.

Diagnostic criteria

Gleyic properties comprise one of the following:

1. a layer with ≥ 95% (exposed area) having colours considered to be reductimorphic, that have:
   a. a Munsell colour hue of N, 10Y, GY, G, BG, B, PB, moist; ***or***
   b. a Munsell colour hue of 2.5Y or 5Y with a chroma of ≤ 2, moist; ***or***
2. a layer with > 5% (exposed area) mottles, the colour of which is considered to be oximorphic, that:
   a. are predominantly around root channels, and if soil aggregates are present, predominantly at or near the surfaces of the aggregates; ***and***
   b. have, moist, a Munsell colour hue ≥ 2.5 units redder than the surrounding material and a Munsell colour chroma ≥ 1 unit higher than the surrounding material; ***or***

3. a combination of two layers: a layer fulfilling diagnostic criterion 2 and a directly underlying layer fulfilling diagnostic criterion 1.

Field identification

Gleyic properties result from a redox gradient between groundwater and the capillary fringe causing an uneven distribution of iron or manganese (hydr-)oxides. In the lower part of the soil and/or inside the soil aggregates, the oxides are either transformed into insoluble Fe/Mn(II) compounds or they are translocated; both processes lead to the absence of colours that have a hue redder than 2.5Y. Translocated Fe and Mn compounds can be concentrated in the oxidized form (Fe[III], Mn[IV]) on soil aggregate surfaces or in biopores (rusty root channels), and towards the surface even in the matrix. Mn concentrations can be recognized by strong effervescence using a 10percent H_2O_2 solution.

Reductimorphic colours reflect permanently wet conditions. In loamy and clayey material, blue-green colours predominate owing to Fe(II, III) hydroxy salts (green rust). If the material is rich in sulfur (S), blackish colours prevail owing to colloidal iron sulfides such as greigite or mackinawite (easily recognized by smell, after applying 1 *M* HCl). In calcareous material, whitish colours are dominant owing to calcite and/or siderite. Sands are usually light grey to white in colour and also often impoverished in Fe and Mn. Bluish-green and black colours are unstable and often oxidize to a reddish brown within a few hours of exposure to air. The upper part of a reductimorphic layer may show up to 5% rusty colours, mainly around channels of burrowing animals or plant roots.

Oximorphic colours reflect oxidizing conditions, as in the capillary fringe and in the surface horizons of soils with fluctuating groundwater levels. Specific colours indicate ferrihydrite (reddish brown), goethite (bright yellowish brown), lepidocrocite (orange), schwertmannite (dark orange) and jarosite (pale yellow). In loamy and clayey soils, the iron oxides/hydroxides are concentrated on soil aggregate surfaces and the walls of larger pores (e.g. old root channels).

In most cases, a layer fulfilling diagnostic criterion 2 overlies a layer fulfilling criterion 1. Many underwater soils (freshwater or seawater) and tidal soils have only a layer that fulfils diagnostic criterion 1 and no layer fulfilling criterion 2.

Relationships with some other diagnostics

Gleyic properties differ from *stagnic* properties. Gleyic properties are caused by an upmoving reducing agent (mostly groundwater) leading to an underlying strongly reduced layer and an overlying layer with oximorphic colours near the soil aggregate surfaces. (In some soils only one of these layers is present.) *Stagnic* properties are caused by stagnation of an intruding reducing agent (mostly rainwater) leading to an overlying reduced layer and an underlying layer with oximorphic colours inside the soil aggregates. (In some soils, only one of these layers is present.)

Lithic discontinuity

General description

Lithic discontinuities (from Greek *lithos*, stone, and Latin *continuare*, to continue) are significant differences in particle-size distribution or mineralogy that represent differences in parent material within a soil. A lithic discontinuity can also denote an age difference. The different strata may have the same or a different mineralogy.

Diagnostic criteria

When comparing layers directly superimposed on the other, a lithic discontinuity requires one or more of the following:

1. an abrupt difference in particle-size distribution that is not solely associated with a change in clay content resulting from pedogenesis; ***or***

2. both of the following:

    a. one or more of the following, calculated for the respective contents in the fine earth fraction:

        i. a difference of ≥ 25% in the ratio coarse sand to medium sand, ***and*** a difference of ≥ 5% (absolute) in the content of coarse sand and/or medium sand; ***or***

        ii. a difference of ≥ 25% in the ratio coarse sand to fine sand, ***and*** a difference of ≥ 5% (absolute) in the content of coarse sand and/or fine sand; ***or***

        iii. a difference of ≥ 25% in the ratio medium sand to fine sand, ***and*** a difference of ≥ 5% (absolute) in the content of medium sand and/or fine sand; ***and***

    b. the differences do not result from original variation within the parent material in the form of a patchwise distribution of different particle size fractions within a layer; ***or***

3. rock fragments that do not have the same lithology as the underlying *continuous rock*; ***or***

4. a layer containing rock fragments without weathering rinds overlying a layer containing rocks with weathering rinds; ***or***

5. a layer with angular rock fragments overlying or underlying a layer with rounded rock fragments; ***or***

6. a layer with a larger content of coarse fragments overlying a layer with a smaller content of coarse fragments; ***or***

7. abrupt differences in colour not resulting from pedogenesis; ***or***

8. marked differences in size and shape of resistant minerals between superimposed layers (as shown by micromorphological or mineralogical methods); ***or***

9. differences in the TiO_2/ZrO_2 ratios of the sand fraction by a factor of 2.

Additional characteristics

In some cases, a lithic discontinuity may be suggested by one of the following: a horizontal line of rock fragments (stone line) overlying and underlying layers with lesser amounts of rock fragments, or a decreasing percentage of rock fragments with increasing depth. On the other hand, the sorting action of small fauna such as termites can produce similar effects in what would initially have been lithicly uniform parent material.

Diagnostic criterion 2 is illustrated by the following example:

Layer 1: 20% coarse sand, 10% medium sand → ratio coarse sand to medium sand: 2.

Layer 2: 15% coarse sand, 10% medium sand → ratio coarse sand to medium sand: 1.5.

Difference in ratios: 25%

Difference in contents of coarse sand (absolute): 5%

Difference in contents of medium sand (absolute): 0

Result: between the two layers, there is a lithic discontinuity.

Generally, the formula for calculating differences in ratios is:

$$ABS(ratio_i-ratio_{i+1})/MAX(ratio_i; ratio_{i+1})*100$$

Protocalcic properties

General description

Protocalcic properties (from Greek *protou*, before, and Latin *calx*, lime) refer to carbonates that are derived from the soil solution and precipitated in the soil. They do not belong to the soil parent material or to other sources such as dust. These carbonates are called secondary carbonates. For protocalcic properties, they should be permanent and be present in significant quantities.

Diagnostic criteria

Protocalcic properties refer to carbonate accumulations that show one or more of the following:

1. disrupt the soil structure or fabric; ***or***
2. occupy ≥ 5% of the soil volume with masses, nodules, concretions or spheroidal aggregates (*white eyes*) that are soft and powdery when dry; ***or***
3. cover with soft coatings ≥ 50% of structural faces, pore surfaces or undersides of rock or cemented fragments, thick enough to be visible when moist; ***or***
4. form permanent filaments (*pseudomycelia*).

Additional characteristics

Accumulations of secondary carbonates qualify as protocalcic properties only if they are permanent and do not come and go with changing moisture conditions. This can be checked by spraying some water.

Relationships with some other diagnostics

Stronger accumulations of secondary carbonates may qualify for a *calcic* horizon, or if cemented or indurated, for a *petrocalcic* horizon. *Calcaric* material refers to primary carbonates.

Reducing conditions

Diagnostic criteria

Reducing conditions (from Latin *reducere*, to draw back) show one or more of the following:

1. a negative logarithm of the hydrogen partial pressure (rH, calculated as $Eh \cdot 29^{-1} + 2 \cdot pH$) of < 20; ***or***

2. the presence of free Fe^{2+}, as shown on a freshly broken and smoothed surface of a field-wet soil by the appearance of a strong red colour after wetting it with a 0.2percent α,α-dipyridyl solution in 10percent acetic acid; ***or***

3. the presence of iron sulfide; ***or***

4. the presence of methane.

Caution: α,α-dipyridyl solution is toxic if swallowed and harmful if absorbed through skin or inhaled. It has to be used with care. In soil materials with a neutral or alkaline soil reaction it may not give the strong red colour.

Retic properties

General description

Retic properties (from Latin *rete*, net) describe the interfingering of coarser-textured *albic* material into a finer-textured *argic* or *natric* horizon. The interfingering coarser-textured *albic* material is characterized by a partial removal of clay and free iron oxides. There may be also coarser-textured *albic* material falling from the overlying horizon into cracks in the *argic* or *natric* horizon. The interfingering coarser-textured *albic* material is found as vertical and horizontal whitish intercalations on the faces and edges of soil aggregates.

Diagnostic criteria

Retic properties refer to a combination of stronger coloured parts and lighter coloured parts within the same layer, with all of the following:

1. the stronger coloured parts belong to an *argic* or *natric* horizon; ***and***

2. the lighter coloured parts consist of *albic* material; ***and***

3. the stronger coloured parts have, compared with the lighter coloured parts, the following Munsell colour, moist:

   a. a hue ≥ 2.5 units redder, ***or***

   b. a value ≥ 1 unit lower, ***or***

   c. a chroma ≥ 1 unit higher; ***and***

4. the clay content of the stronger coloured parts is higher compared with the lighter coloured parts, as specified for the *argic* or *natric* horizon; ***and***

5. the lighter coloured parts are ≥ 0.5 cm wide; ***and***

6. the lighter coloured parts start at the upper limit of the *argic* or *natric* horizon; ***and***

7. the lighter coloured parts occupy areas ≥ 10 and ≤ 90% in both vertical and horizontal sections, within the upper 10 cm of the *argic* or *natric* horizon; ***and***

8. do not occur within a plough layer.

Relationships with some other diagnostics

Retic properties include the special case of *albeluvic glossae*. The *argic* or *natric* horizon that exhibit retic properties may also satisfy the requirements of a *fragic* horizon. A layer with retic properties may also exhibit *stagnic* properties with or without *reducing conditions*. The layer with the retic properties is overlain by a layer with *albic* material, by a *cambic* horizon or by a plough layer.

Shrink-swell cracks

General description

Shrink-swell cracks open and close due to shrinking and swelling of clay minerals with changing water content of the soil. They may be evident only when the soil is dry. They control the infiltration and percolation of water, even if they are filled with material from the surface.

Diagnostic criteria

Shrink-swell cracks:

1. open and close with changing water content of the soil; ***and***

2. are ≥ 0.5 cm wide, when the soil is dry, with or without infillings of material from the surface.

Relationships with some other diagnostics

Shrink-swell cracks are referred to in the diagnostic criteria of the *protovertic* horizon, the *vertic* horizon and in the Key to the Reference Soil Groups (where reference is made to their depth requirements).

Sideralic properties

General description

Sideralic properties (from Greek *sideros*, iron, and Latin *alumen*, alum) refer to mineral soil material that has a relatively low CEC.

Diagnostic criteria

Sideralic properties occur in a subsurface layer and require one or both of the following:

1. a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay; ***or***

2. both of the following:

a. a CEC (by 1 *M* NH_4OAc, pH 7) of < 4 $cmol_c$ kg^{-1} soil; ***and***

b. a Munsell colour chroma of ≥ 5, moist.

Relationships with some other diagnostics

Sideralic properties are also present in *ferralic* horizons and in soil materials that satisfy the requirements of a *ferralic* horizon except the texture requirement.

Stagnic properties

General description

Soil materials develop stagnic properties (from Latin *stagnare*, to stagnate) if they are, at least temporarily, saturated with surface water (or were saturated in the past, if now drained) for a period long enough that allows *reducing conditions* to occur (this may range from a few days in the tropics to a few weeks in other areas). In some soils with stagnic properties, the *reducing conditions* are caused by the intrusion of other liquids such as gasoline.

Diagnostic criteria

Stagnic properties comprise one of the following:

1. a mottled layer with two or more colours and one or both of the following:
   a. mottles and/or concretions and/or nodules, the colour of which is considered to be oximorphic, that:
      i. are, if soil aggregates are present, predominantly inside the aggregates; ***and***
      ii. are black, surrounded by lighter-coloured material, ***or*** have, moist, a Munsell colour hue ≥ 2.5 units redder than the surrounding material and a Munsell colour chroma ≥ 1 unit higher than the surrounding material; ***or***
   b. parts, the colour of which is considered to be reductimorphic, that:
      i. are predominantly around root channels, and if soil aggregates are present, predominantly at or near the surfaces of the aggregates; ***and***
      ii. have, moist, a Munsell colour value ≥ 1 unit higher than the surrounding material and a Munsell colour chroma ≥ 1 unit lower than the surrounding material; ***or***
2. a layer with *albic* material, the colour of which is considered as being reductimorphic, above an *abrupt textural difference*; ***or***
3. a combination of two layers: a layer with *albic* material, the colour of which is considered as being reductimorphic, and a directly underlying mottled layer with the colour properties as specified in diagnostic criterion 1.

Additional characteristics

Stagnic properties result from a reduction of iron and/or manganese (hydr-)oxides around the larger pores. Mobilized Mn and Fe may be washed out laterally resulting in albic material (especially in the upper part of the profile that is in many soils coarser textured) or may migrate into the interiors of the soil aggregates where they are reoxidized (especially in the lower part of the profile).

If the stagnic properties are weakly expressed, the reductimorphic and oximorphic colours cover only some parts of the soil volume, and the other parts show the original colour that prevailed in the soil before the redox processes started. If the stagnic properties are strongly expressed, the whole volume of the fine earth shows either reductimorphic or oximorphic colours. In the latter case, the chroma requirements of criteria 1a and 1b sum up to a difference of two units.

Relationships with some other diagnostics

Stagnic properties differ from g*leyic* properties. Stagnic properties are caused by stagnation of an intruding reducing agent (mostly rainwater) leading to an overlying reduced layer and an underlying layer with oximorphic colours inside the soil aggregates. (In some soils, only one of these layers is present.) *Gleyic* properties are caused by an upmoving reducing agent (mostly groundwater) leading to an underlying strongly reduced layer and an overlying layer with oximorphic colours near the soil aggregate surfaces. (In some soils, only one of these layers is present.)

Takyric properties

General description

Takyric properties (from Turkic languages *takyr*, barren land) are related to a heavy-textured surface layer comprising a surface crust and a platy or massive structure. It occurs under arid conditions in periodically flooded soils.

Diagnostic criteria

Takyric properties show:

1 *aridic* properties; ***and***

2. a surface crust that has all of the following:

   a. thickness enough that it does not curl entirely upon drying; ***and***

   b. polygonal cracks ≥ 2 cm deep when the soil is dry; ***and***

   c. a texture class of clay loam, silty clay loam or clay; ***and***

   d. very hard consistence when dry, and plastic or very plastic and sticky or very sticky consistence when wet; ***and***

   e. an electrical conductivity (EC_e) of the saturated extract of < 4 dS m^{-1}, or less than that of the layer directly below the surface crust; ***and***

   f. a platy or massive structure.

Field identification

Takyric properties occur in depressions in arid regions, where surface water, rich in clay and silt but relatively low in soluble salts, accumulates and leaches salts out of the upper soil horizons. This causes clay dispersion and the formation of a thick, compact, fine-textured crust with prominent polygonal cracks when dry. The crust often contains ≥ 80% clay and silt.

Relationships with some other diagnostics

Takyric properties occur in association with many diagnostic horizons, the most important ones being the *natric*, *salic*, *gypsic*, *calcic* and *cambic* horizons. The low EC and low soluble-salt content of takyric properties set them apart from the *salic* horizon.

Vitric properties

General description

Vitric properties (from Latin *vitrum*, glass) apply to layers with volcanic glass and other primary minerals derived from volcanic ejecta and which contain a limited amount of short-range-order minerals or organo-metallic complexes.

Diagnostic criteria

Vitric properties[19] require:

1. ≥ 5% (by grain count) volcanic glass, glassy aggregates and other glass-coated primary minerals, in the fraction ≥ 0.02 and ≤ 2 mm; ***and***

2. an Al_{ox} + ½Fe_{ox} value of ≥ 0.4%; ***and***

3. a phosphate retention of ≥ 25%.

Field identification

Vitric properties can occur in a surface layer. However, they can also occur under some tens of centimetres of recent pyroclastic deposits. Layers with vitric properties can have an appreciable amount of organic matter. The sand and coarse silt fractions of layers with vitric properties have a significant amount of unaltered or partially altered volcanic glass, glassy aggregates and other glass-coated primary minerals (coarser fractions may be checked by using a ×10 hand-lens; finer fractions may be checked by using a microscope).

Relationships with some other diagnostics

Vitric properties are, on the one hand, closely linked with *andic* properties, into which they may eventually develop. For some time during this development, a layer may show both the amount of volcanic glasses required for the vitric properties and the characteristics of *andic* properties. On the other hand, layers with vitric properties develop from *tephric* materials.

Chernic, *mollic* and *umbric* horizons may exhibit vitric properties as well.

Yermic properties

General description

Yermic properties (from Spanish *yermo*, desert) are found in a surface horizon that usually, but not always, consists of surface accumulations of rock fragments (*desert pavement*), embedded in a loamy vesicular layer that may be covered by a thin aeolian sand or loess layer.

Diagnostic criteria

Yermic properties show:

1. *aridic* properties; ***and***

[19] Adapted after Takahashi, Nanzyo and Shoji (2004) and findings of the COST 622 Action.

2. one or more of the following:

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

    b. a pavement associated with a vesicular layer; ***or***

    c. a vesicular layer below a platy surface layer.

Field identification

Yermic properties comprise a pavement and/or a vesicular layer that has a loamy texture. The vesicular layer shows a polygonal network of desiccation cracks, often filled with in-blown material, that extend into the underlying layers. The surface layers have a weak to moderate platy structure.

Relationships with some other diagnostics

Yermic properties often occur in association with other diagnostics 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 deposits, without a vesicular layer.

DIAGNOSTIC MATERIALS

Albic material

General description

Albic material (from Latin *albus*, white) is predominantly light-coloured fine earth, from which organic matter and/or 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.

Diagnostic criteria

Albic material is fine earth that:

1. has in ≥ 90% of its volume a Munsell colour, dry, with:

   a. a value of 7 or 8 and a chroma of ≤ 3; ***or***

   b. a value of 5 or 6 and a chroma of ≤ 2; ***and***

2. has in ≥ 90% of its volume a Munsell colour, moist, with:

   a. a value of 6, 7 or 8 and a chroma of ≤ 4; ***or***

   b. a value of 5 and a chroma of ≤ 3; ***or***

   c. a value of 4 and a chroma of ≤ 2; ***or***

   d. a value of 4 and a chroma of 3 if the colour is derived from parent material that has a hue of 5YR or redder, and the chroma is due to the colour of uncoated silt or sand grains.

Field identification

Identification in the field depends on soil colours. In addition, a ×10 hand lens may be used to ascertain that sand and silt grains are free of coatings. Albic material may exhibit a considerable shift in chroma when wetted. Such soils occur for example in southern Africa.

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 diagnostics

Layers with albic material are normally overlain by humus-enriched surface layers but may also be at the surface as a result of erosion or artificial removal of the surface layer. Albic materials represent a strong expression of eluviation and are therefore generally associated with an eluvial horizon. As such, they usually overlie an illuvial horizon such as an *argic*, *natric* or *spodic* horizon. In sandy materials, layers with albic material can reach considerable thickness, up to several metres, especially in humid tropical regions, and associated diagnostic horizons may be hard to establish. Albic material may also be the result of reduction processes. It may also occur above a *plinthic* horizon.

Artefacts

Diagnostic criteria

Artefacts (from Latin *ars*, art, and *factus*, made) are solid or liquid substances that are:

1. one or both of the following:

    a. created or substantially modified by humans as part of an industrial or artisanal manufacturing process; ***or***

    b. brought to the surface by human activity from a depth, where they were not influenced by surface processes, and deposited in an environment, where they do not commonly occur, with properties substantially different from the environment where they are placed; ***and***

2. have substantially the same chemical and mineralogical properties as when first manufactured, modified or excavated.

Additional characteristics

Examples of artefacts are bricks, pottery, glass, crushed or dressed stone, wooden boards, industrial waste, garbage, processed oil products, bitumen, mine spoil and crude oil.

Relationships with some other diagnostics

Technic hard material and geomembranes, intact, fractured or composed, also fulfil the diagnostic criteria of artefacts.

Calcaric material

General description

Calcaric material (from Latin *calcarius*, containing lime) refers to material that contains ≥ 2% calcium carbonate equivalent. The carbonates are inherited from the parent material.

Diagnostic criteria

Calcaric material effervesces strongly with 1 *M* HCl in most of those parts of the fine earth that

1. do not disrupt the soil structure or fabric; ***and***

2. do not belong to masses, nodules, concretions or spheroidal aggregates (white eyes) that are soft and powdery when dry; ***and***

3. do not belong to soft coatings of structural faces or pore surfaces; ***and***

4. do not form permanent filaments (pseudomycelia).

Relationships with some other diagnostics

Calcic and *petrocalcic* horizons have at least some contribution of secondary carbonates. *Protocalcic* properties refer to lesser accumulations of secondary carbonates. A layer may consist of calcaric material and, in addition, show *protocalcic* properties.

Colluvic material

General description

Colluvic material (from Latin *colluvio*, mixture) is a heterogeneous mixture of material that, by gravitational action, has moved down a slope. It has been transported as a result of erosional wash or soil creep, and the transport may have been accelerated by land-use practices (e.g. deforestation, ploughing, downhill tillage, structure degradation). It has been formed in relatively recent times (mostly Holocene). It normally accumulates in slope positions, in depressions or above a barrier on a low-grade slope (natural or human-made, e.g. hedge walls).

Diagnostic criteria

Colluvic material:

1. is found on slopes, footslopes, fans or similar relief positions; ***and***

2. shows evidence of downslope movement; ***and***

3. is not of fluviatile, lacustrine or marine origin; ***and***

4. if it buries a mineral soil, it has a lower bulk density than the buried soil material.

Field identification

Colluvic material can be of any size grade from clay to sand. Some coarse fragments may be included. Colluvic material is generally imperfectly sorted. It may show some gross stratification but stratification is not a typical feature due to the diffuse or chaotic nature of the deposition process. Colluvic material tends to occupy gently sloping to moderately steep sloping (2-30%) areas (footslopes, concave slope positions). Charcoal or small *artefacts* such as pieces of bricks, ceramics and glass may be present in colluvic material. In many cases, colluvic material has a *lithic discontinuity* at its base.

The upper part of the colluvic material shows characteristics (fine earth texture, colour, pH and *soil organic carbon* content) similar to the surface layer of the source in the neighbourhood. In extreme cases, the profile in the colluvic material mirrors the eroded soil profile of upward slope positions, with topsoil material buried under former subsoil material. Good indication of colluviation in a landscape is varying colour of the soil surface between convex and concave positions.

Rapid mass movements such as in landslides, slumps, treethrows are not generally included as processes forming colluvic material.

Dolomitic material

Diagnostic criteria

Dolomitic material (named after the French geoscientist *Déodat de Dolomieu*) effervesces strongly with heated 1 *M* HCl in most of the fine earth fraction. It applies to material that contains ≥ 2% of a mineral that has a ratio $CaCO_3/MgCO_3 < 1.5$. With non-heated HCl it gives only a retarded and weak effervescence.

Fluvic material

General description

Fluvic material (from Latin *fluvius*, river) refers to fluviatile, marine and lacustrine sediments that receive fresh material or have received it in the past and still show stratification.

Diagnostic criteria

Fluvic material

1. is of fluviatile, marine or lacustrine origin; ***and***

2. has one or both of the following:

   a. obvious stratification (including stratification tilted by cryoturbation) in ≥ 25% of the soil volume over a specified depth (including strata thicker than the specified depth); ***or***

   b. stratification evidenced by a layer with all of the following:

      i. has ≥ 0.2% *soil organic carbon*; ***and***

      ii. has a content of *soil organic carbon* ≥ 25% (relative) and ≥ 0.2% (absolute) higher than in the overlying layer; ***and***

      iii. does not form part of a *spodic* or *sombric* horizon.

Field identification

Stratification may be reflected in different ways:

- variation in texture and/or content or nature of coarse fragments, or
- different colours related to the source materials, or
- alternating lighter and darker coloured soil layers, indicating an irregular decrease in soil organic carbon content with depth.

Additional characteristics

Fluvic material is always associated with water bodies (e.g. rivers, lakes, the sea) and can therefore be distinguished from *colluvial* material.

Gypsiric material

Diagnostic criteria

Gypsiric material (from Greek *gypsos*, gypsum) is mineral material that contains ≥ 5% gypsum (by volume) in those parts of the fine earth that do not contain secondary gypsum.

Relationships with some other diagnostics

Gypsic and *petrogypsic* horizons have secondary gypsum, at least to some extent.
A layer may consist of gypsiric material and, in addition, contain some secondary gypsum.

Hypersulfidic material

General description

Hypersulfidic material is capable of severe acidification as a result of the oxidation of inorganic sulfidic compounds contained within it. It has a positive net acidity using acid-base accounting approaches[20]. Hypersulfidic material is conceptually the same as defined in WRB 2006 as *sulfidic* material is also known as 'potential acid sulfate soil'.

Diagnostic criteria

Hypersulfidic material has:

1. ≥ 0.01% inorganic sulfidic S (dry mass); ***and***

2. a pH ≥ 4 that undergoes a drop in pH < 4 (1:1 by mass in water, or in a minimum of water to permit measurement) when a 2–10 mm thick layer is incubated aerobically at field capacity until:

   a. the pH drop is ≥ 0.5 pH units; ***or***

   b. after ≥ 8 weeks, decrease in pH is < 0.1 pH units over a period of ≥ 14 days; ***or***

   c. after ≥ 8 weeks, the pH begins to increase.

Field identification

Hypersulfidic material is seasonally or permanently waterlogged or forms under largely anaerobic conditions. It has a Munsell colour hue of N, 5Y, 5GY, 5BG, or 5G; a value of 2, 3 or 4; and a chroma of 1, all moist. If the soil is disturbed, an odour of hydrogen sulfide (rotten eggs) may be noticed. This is accentuated by application of 1 *M* HCl.

For a quick screening test that is not definitive, a 10 g sample treated with 50 ml of 30% H_2O_2 will show a fall in pH to ≤ 2.5. Final assessment depends on incubation testing.

Caution: H_2O_2 is a strong oxidant and sulfides and organic matter will froth violently in a test tube that may become very hot.

Relationships with some other diagnostics

Hypersulfidic material is a special case of *sulfidic* material. Acidification of hypersulfidic material usually causes the development of a *thionic* horizon.

Hyposulfidic material

General description

Hyposulfidic material is *sulfidic* material that is not capable of severe acidification resulting from the oxidation of inorganic sulfidic compounds contained within it. Although oxidation does not lead to the formation of acid sulfate soils, hyposulfidic material is an important environmental hazard due to processes related to inorganic sulfides. Hyposulfidic material has a self-neutralizing capacity, usually due to the presence of calcium carbonate, i.e. it has a zero or negative net acidity using acid-base accounting approaches[21].

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[20] The general form of acid-base accounting for sulfidic material is: *Net acidity = Potential sulfidic acidity + Existing acidity - Acid neutralizing capacity/Fineness factor.*

[21] The general form of acid-base accounting for sulfidic materials is: *Net acidity = Potential sulfidic acidity + Existing acidity - Acid neutralizing capacity/Fineness factor.*

Diagnostic criteria
Hyposulfidic material:

1. has ≥ 0.01% inorganic sulfidic S (dry mass); ***and***

2. does not consist of *hypersulfidic* material.

Field identification
Hyposulfidic material forms in similar environments to *hypersulfidic* material and morphologically may be indistinguishable from it. However, it is less likely to be coarse in texture. The hydrogen peroxide screening test (see *hypersulfidic* material) may also be indicative, but final assessment depends on incubation testing. Field tests for fine earth carbonate may be used to indicate whether the soil has some self-neutralizing capacity.

Relationships with some other diagnostics
Hyposulfidic material is a special case of *sulfidic* material. Acidification of hyposulfidic material usually does not cause the development of a *thionic* horizon.

Limnic material
Diagnostic criteria
Limnic material (from Greek *limnae*, pool) includes both *organic* and *mineral* materials that are:

1. deposited in water by precipitation or through action of aquatic organisms, such as diatoms and other algae; ***or***

2. derived from underwater and floating aquatic plants and subsequently modified by aquatic animals.

Field identification
Limnic material is formed as subaquatic deposits. (After drainage it may occur at the surface.) Four types of limnic material are distinguished:

1. *Coprogenous earth or sedimentary peat*: dominantly organic, identifiable through many faecal pellets, Munsell colour value of ≤ 4 moist, slightly viscous water suspension, non- or slightly plastic and non-sticky consistence, shrinking upon drying, difficult to rewet after drying, and cracking along horizontal planes.

2. *Diatomaceous earth*: mainly diatoms (siliceous), identifiable by irreversible changing of the matrix colour (Munsell colour value of 3, 4 or 5 in field moist or wet condition) as a result of the irreversibly shrinkage of the organic coatings on diatoms (use 440× microscope).

3. *Marl*: strongly calcareous, identifiable by a Munsell colour value of ≥ 5 moist, and a reaction with 1 *M* HCl. The colour of marl usually does not change upon drying.

4. *Gyttja*: small coprogenic aggregates of strongly humified organic matter and minerals of predominantly clay to silt size, ≥ 0.5% *soil organic carbon*, a Munsell colour hue of 5Y, GY or G, moist, strong shrinkage after drainage and an rH value of ≥ 13.

Mineral material

General description

In mineral material (from Celtic *mine*, mineral), the soil properties are dominated by mineral components.

Diagnostic criteria

Mineral material has < 20% *soil organic carbon* in the fine earth fraction (by mass).

Relationships with some other diagnostics

Material that has ≥ 20% *soil organic carbon* is *organic* material.

Organic material

General description

Organic material (from Greek *organon*, tool) consists of a large amount of organic debris that accumulates under either wet or dry conditions and in which the mineral component does not significantly influence the soil properties.

Diagnostic criteria

Organic material has ≥ 20% *soil organic carbon* in the fine earth fraction (by mass).

Relationships with some other diagnostics

Histic and *folic* horizons consist of organic material. Material that has < 20% *soil organic carbon* is *mineral* material.

Ornithogenic material

General description

Ornithogenic material (from Greek *ornithos*, bird, and *genesis*, origin) is material with strong influence of bird excrement. It often has a high content of gravel that has been transported by birds.

Diagnostic criteria

Ornithogenic material has:

1. remnants of birds or bird activity (bones, feathers, and sorted gravel of similar size); ***and***

2. a P_2O_5 content of ≥ 0.25% in 1percent citric acid.

Soil organic carbon

Diagnostic criteria

Soil organic carbon is organic carbon that does not meet the diagnostic criteria of *artefacts*.

Relationships with some other diagnostics

For organic carbon meeting the criteria of *artefacts*, the *Garbic* or the *Carbonic* qualifier may apply.

Sulfidic material

General description

Sulfidic material (from Latin *sulpur*, sulfur) is a deposit containing detectable inorganic sulfides. Sulfidic material accommodates a diverse range of seasonally or permanently waterlogged materials, including artefacts such as mine spoil. Sulfidic material often becomes extremely acid when drained (if so, it is termed *hypersulfidic* material).

Diagnostic criteria

Sulfidic material has:

1. a pH (1:1 in water) ≥ 4; ***and***

2. ≥ 0.01% inorganic sulfidic S (dry mass).

Field identification

In moist or wet conditions, deposits containing sulfide often show a golden shine, the colour of pyrite. Munsell colours range: hues of N, 5Y, 5GY, 5BG, or 5G; values of 2, 3 or 4; chroma always 1. The colour is usually unstable, and blackens upon exposure. Sulfidic clay is usually practically unripe. If the soil is disturbed, a whiff of hydrogen sulfide ('rotten eggs') may be noticed. This is accentuated by application of 1 *M* HCl.

Relationships with some other diagnostics

Two kinds of sulfidic material are distinguished, based on the type and quantity of oxidizable sulfur minerals present and the neutralizing capacity of the soil material: *hypersulfidic* and *hyposulfidic* material. Wherever possible, one of these more specifically defined diagnostic materials should be used for classification. Acidification of hypersulfidic material usually causes the development of a *thionic* horizon.

Technic hard material

Diagnostic criteria

Technic hard material (from Greek *technikos*, skilfully made or constructed):

1. is consolidated material resulting from an industrial process; ***and***

2. has properties substantially different from those of natural materials; ***and***

3. is continuous ***or*** has free space covering < 5% of its horizontal extension.

Additional characteristics

Examples of technic hard material are asphalt, concrete or a continuous layer of worked stones.

Relationships with some other diagnostics

Technic hard material, intact, fractured or composed, also fulfils the diagnostic criteria of *artefacts*.

Tephric material

General description

Tephric material[22] (from Greek *tephra*, pile ash) consists either of tephra, i.e. unconsolidated, non- or only slightly weathered pyroclastic products of volcanic eruptions (including ash, cinders, lapilli, pumice, pumice-like vesicular pyroclastics, blocks and volcanic bombs), or of tephric deposits, i.e. tephra that has been reworked and mixed with material from other sources. This includes tephric loess, tephric blown sand and volcanogenic alluvium.

Diagnostic criteria

Tephric material has:

1. ≥ 30% (by grain count) volcanic glass, glassy aggregates and other glass-coated primary minerals in the fraction between ≥ 0.02 and ≤ 2 mm; ***and***

2. no *andic* or *vitric* properties.

Relationships with some other diagnostics

Progressive weathering of tephric material will develop *vitric* properties; it is then no longer regarded as tephric material.

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

Chapter 4

Key to the Reference Soil Groups with lists of principal and supplementary qualifiers

Before using the key, please read the 'Rules for classifying soils' (Chapter 2).

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Soils having *organic* material: 1. starting at the soil surface and having a thickness of ≥ 10 cm and directly overlying: a. ice, *or* b *continuous rock* or *technic hard* material, *or* c. coarse fragments, the interstices of which are filled with *organic* material; *or* 2. starting ≤ 40 cm from the soil surface and having within ≤ 100 cm of the soil surface a combined thickness of *either*: a. ≥ 60 cm, if ≥ 75% (by volume) of the material consists of moss fibres; *or* b. ≥ 40 cm in other materials. **HISTOSOLS**	Muusic/ Rockic/ Mawic Cryic Thionic Folic Floatic/ Subaquatic/ Tidalic Fibric/ Hemic/ Sapric Leptic Murshic/ Drainic Ombric/ Rheic Hyperskeletic/ Skeletic Andic Vitric Calcic Dystric/ Eutric	Alcalic Dolomitic/ Calcaric Fluvic Gelic Hyperorganic Isolatic Lignic Limnic Magnesic Mineralic Novic Ornithic Petrogleyic Placic Relocatic Salic Sodic Sulfidic Technic Tephric Toxic Transportic Turbic

Overview of Key to Reference Soil Groups									
Histosols	**85**	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *hortic*, *irragric*, *plaggic* or *terric* horizon ≥ 50 cm thick; *or* 2. an *anthraquic* horizon and an underlying *hydragric* horizon with a combined thickness of ≥ 50 cm; *or* 3. a *pretic* horizon, the layers of which have a combined thickness of ≥ 50 cm, within ≤ 100 cm of the mineral soil surface. **ANTHROSOLS**	Hydragric/ Irragric/ Hortic/ Plaggic/ Pretic/ Terric	Acric/ Lixic/ Alic/ Luvic Alcalic/ Dystric/ Eutric Andic Arenic/ Clayic/ Loamic/ Siltic Calcic Dolomitic/ Calcaric Escalic Ferralic/ Sideralic Fluvic Gleyic Endoleptic Novic Oxyaquic Salic Skeletic Sodic Spodic Stagnic Technic Toxic Vertic Vitric

<table>
<tr><th>Key to the Reference Soil Groups</th><th>Principal qualifiers</th><th>Supplementary qualifiers</th></tr>
<tr><td>Other soils:
1. with all of the following:
a. having ≥ 20% (by volume, weighted average) artefacts in the upper 100 cm from the soil surface or to continuous rock or technic hard material or a cemented or indurated layer; and
b. not having a layer containing artefacts that qualifies as an argic, chernic, duric, ferralic, ferric, fragic, hydragric, natric, nitic, petrocalcic, petroduric, petrogypsic, petroplinthic, pisoplinthic, plinthic, spodic or vertic horizon starting ≤ 100 cm from the soil surface, unless buried; and
c. not having continuous rock or a cemented or indurated layer starting ≤ 10 cm from the soil surface; or
2. having a continuous, very slowly permeable to impermeable, constructed geomembrane of any thickness starting ≤ 100 cm from the soil surface; or
3. having technic hard material starting ≤ 5 cm from the soil surface.

TECHNOSOLS[a]</td><td>Ekranic
Linic
Urbic
Spolic
Garbic
Cryic
Isolatic
Leptic
Subaquatic/ Tidalic
Reductic
Hyperskeletic</td><td>Alcalic/ Dystric/ Eutric
Andic
Anthraquic/ Irragric/ Hortic/ Plaggic/ Pretic/ Terric
Archaic
Arenic/ Clayic/ Loamic/ Siltic
Aridic
Calcic
Cambic
Carbonic
Densic
Dolomitic/ Calcaric
Drainic
Fluvic
Folic/ Histic
Gleyic
Gypsic
Gypsiric
Humic/ Ochric
Hyperartefactic
Immissic
Laxic
Lignic
Mollic/ Umbric
Novic
Oxyaquic
Raptic
Relocatic
Salic
Sideralic
Skeletic
Sodic
Protospodic
Stagnic
Sulfidic
Tephric
Thionic
Toxic
Transportic
Vitric</td></tr>
</table>

a Buried soils occur frequently in this RSG and can be indicated with “over”. Buried diagnostic horizons can be indicated with the Thapto- specifier followed by a qualifier. For soils with a geomembrane or *technic hard material*, the Supra- specifier is provided to describe soil material above the geomembrane or above the *technic hard material.* It can be combined with any qualifier and for this purpose, the thickness and depth requirements of these qualifiers are waived.

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having:	Glacic	Abruptic
1. a *cryic* horizon starting ≤ 100 cm from the soil surface; *or*	Turbic	Albic
2. a *cryic* horizon starting ≤ 200 cm from the soil surface *and* evidence of cryoturbation (frost heave, cryogenic sorting, thermal cracking, ice segregation, patterned ground, etc.) in some layer within ≤ 100 cm of the soil surface.	Subaquatic/ Tidalic/ Reductaquic/ Oxyaquic	Alcalic/ Dystric/ Eutric
	Leptic	Andic
	Protic	Arenic/ Clayic/ Loamic/ Siltic
	Folic/ Histic	Dolomitic/ Calcaric
	Mollic/ Umbric	Drainic
	Natric	Fluvic
CRYOSOLS	Salic	Gypsiric
	Spodic	Humic/ Ochric
	Alic/ Luvic	Limnic
	Calcic	Magnesic
	Cambic	Nechic
	Hyperskeletic/ Skeletic	Novic
	Haplic	Ornithic
		Raptic
		Sodic
		Sulfidic
		Technic
		Tephric
		Thixotropic
		Toxic
		Transportic
		Vitric
		Yermic/ Aridic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. one of the following: a. *continuous rock* or *technic hard* material starting ≤ 25 cm from the soil surface; *or* b. < 20% (by volume) fine earth, averaged over a depth of 75 cm from the soil surface or to *continuous rock* or *technic hard* material, whichever is shallower; *and* 2. no *calcic*, *chernic, duric, gypsic, petrocalcic, petroduric, petrogypsic, petroplinthic* or *spodic* horizon. **LEPTOSOLS**	Nudilithic/ Lithic Technoleptic Hyperskeletic/ Skeletic Subaquatic/ Tidalic Folic/ Histic Rendzic/ Mollic/ Umbric Cambic/ Brunic Gypsiric Dolomitic/ Calcaric Dystric/ Eutric	Andic Arenic/ Clayic/ Loamic/ Siltic Aric Protocalcic Colluvic Drainic Fluvic Gelic Gleyic Humic/ Ochric Isolatic Lapiadic Nechic Novic Ornithic Oxyaquic Placic Protic Raptic Salic Sodic Protospodic Stagnic Sulfidic Takyric/ Yermic/ Aridic Technic Tephric Toxic Transportic Turbic Protovertic Vitric

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	**89**	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having a *natric* horizon starting ≤ 100 cm from the soil surface. **SOLONETZ**	Abruptic Gleyic Stagnic Mollic Salic Gypsic Petrocalcic/ Calcic Fractic Vertic Chromic Nudinatric Haplic	Albic Arenic/ Clayic/ Loamic/ Siltic Neocambic Colluvic Columnic Cutanic Differentic Duric Ferric Fluvic Humic/ Ochric Magnesic Hypernatric Novic Oxyaquic Raptic Retic Skeletic Takyric/ Yermic/ Aridic Technic Toxic Transportic Turbic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *vertic* horizon starting ≤ 100 cm from the soil surface; *and* 2. ≥ 30% clay between the soil surface and the *vertic* horizon throughout; *and* 3. *shrink-swell cracks* that start: a. at the soil surface; *or* b. at the base of a plough layer; *or* c. ≤ 5 cm from the soil surface if there is a surface layer of strong granular structural elements ≤ 10 mm in size (self-mulching surface); *or* d. ≤ 3 cm from the soil surface if there is a surface crust; *and* extend to the *vertic* horizon. **VERTISOLS**	Salic Sodic Leptic Petroduric/ Duric Gypsic Petrocalcic/ Calcic Hydragric/ Anthraquic/ Irragric Pellic Chromic Haplic	Albic Aric Chernic/ Mollic Dolomitic/ Calcaric Drainic Hypereutric Ferric Fractic Gilgaic Gleyic Grumic/ Mazic Gypsiric Humic/ Ochric Magnesic Mesotrophic Novic Raptic Skeletic Stagnic Sulfidic Technic Thionic Toxic

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	**91**	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *salic* horizon starting ≤ 50 cm from the soil surface; *and* 2. no *thionic* horizon starting ≤ 50 cm from the soil surface; *and* 3. not permanently submerged by water and not located below the line affected by tidal water (i.e. not located below the line of mean high water springs). **SOLONCHAKS**	Petrosalic Gleyic Stagnic Mollic Sodic Gypsic Petrocalcic/ Calcic Fluvic Haplic	Aceric Alcalic Arenic/ Clayic/ Loamic/ Siltic Carbonatic/ Chloridic/ Sulfatic Colluvic Densic Dolomitic/ Calcaric Drainic Duric Evapocrustic/ Puffic Folic/ Histic Fractic Gelic Gypsiric Humic/ Ochric Novic Oxyaquic Raptic Hypersalic Skeletic Sulfidic Takyric/ Yermic/ Aridic Technic Toxic Transportic Turbic Vertic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having one of the following: 1. a layer ≥ 25 cm thick, and starting ≤ 40 cm from the mineral soil surface, that has a. *gleyic* properties throughout; *and* b. *reducing conditions* in some parts of every sublayer; *or* 2. both of the following: a. a *mollic* or *umbric* horizon, > 40 cm thick, that has *reducing conditions* in some parts of every subhorizon, from 40 cm below the mineral soil surface to the lower limit of the *mollic* or *umbric* horizon; *and* b. directly underneath the *mollic*/*umbric* horizon, a layer ≥ 10 cm thick, that has its lower limit ≥ 65 cm below the mineral soil surface, and that has: i. *gleyic* properties throughout; *and* ii. *reducing conditions* in some parts of every sublayer. **GLEYSOLS**	Thionic Reductic Subaquatic/ Tidalic Hydragric/ Anthraquic Folic/ Histic Chernic/ Mollic/ Umbric Pisoplinthic/ Plinthic Stagnic Oxygleyic/ Reductigleyic Ferralic/ Sideralic Gypsic Calcic Spodic Fluvic Dolomitic/ Calcaric Dystric/ Eutric	Abruptic Acric/ Lixic/ Alic/ Luvic Alcalic Andic Arenic/ Clayic/ Loamic/ Siltic Aric Colluvic Drainic Fractic Gelic Humic/ Ochric Inclinic Limnic Nechic Novic Petrogleyic Raptic Relocatic Salic Skeletic Sodic Sulfidic Takyric/ Aridic Technic Tephric Toxic Turbic Uterquic Vertic Vitric

Overview of Key to Reference Soil Groups

Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	**Gleysols**	**93**	Stagnosols	100	Calcisols	107	Arenosols	114
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Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. one or more layers with *andic* or *vitric* properties with a combined thickness of *either*: a. ≥ 30 cm, within ≤ 100 cm of the soil surface and starting ≤ 25 cm from the soil surface; *or* b. ≥ 60% of the entire thickness of the soil, if *continuous rock, technic hard* material or a cemented or indurated layer starts > 25 and ≤ 50 cm from the soil surface; *and* 2. no *argic*, *ferralic*, *petroplinthic*, *pisoplinthic*, *plinthic* or *spodic* horizon, unless buried deeper than 50 cm from the mineral soil surface. **ANDOSOLS**[b]	Aluandic/ Silandic Vitric Leptic Hydragric/ Anthraquic Gleyic Hydric Folic/ Histic Chernic/ Mollic/ Umbric Petroduric/ Duric Gypsic Calcic Tephric Skeletic Eutrosilic Dystric/ Eutric	Acroxic Protoandic Arenic/ Clayic/ Loamic/ Siltic Aric Colluvic Dolomitic/ Calcaric Drainic Fluvic Fragic Fulvic/ Melanic Gelic Hyperhumic Nechic Novic Oxyaquic Placic Reductic Sideralic Sodic Protospodic Technic Thixotropic Toxic Transportic Turbic

b Buried soils occur frequently in this RSG and can be indicated with 'over'. Buried diagnostic horizons can be indicated with the Thapto- specifier followed by a qualifier.

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having a *spodic* horizon starting ≤ 200 cm from the mineral soil surface. **PODZOLS**	Ortsteinic Carbic/ Rustic Albic/ Entic Leptic Hortic/ Plaggic/ Pretic/ Terric Folic/ Histic Gleyic Stagnic Umbric Glossic/ Retic Alic Hyperskeletic/ Skeletic Andic Vitric	Abruptic Arenic/ Loamic/ Siltic Aric Neocambic Densic Drainic Endoeutric Fragic Gelic Lamellic Novic Ornithic Oxyaquic Placic Raptic Hyperspodic Technic Toxic Transportic Turbic

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	**Podzols**	**95**	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *plinthic*, *petroplinthic* or *pisoplinthic* horizon starting ≤ 50 cm from the soil surface; *or* 2. a *plinthic* horizon starting ≤ 100 cm from the soil surface; and directly above or below its upper limit, a layer ≥ 10 cm thick, that has: a. *stagnic* properties in which the area of reductimorphic colours plus the area of oximorphic colours is ≥ 50% of the layer's total area; *and* b. *reducing conditions* for some time during the year in the major part of the layer's volume that has the reductimorphic colours. **PLINTHOSOLS**	Petric Pisoplinthic Gibbsic Stagnic Folic/ Histic Mollic/ Umbric Albic Geric Haplic	Abruptic Acric/ Lixic Arenic/ Clayic/ Loamic/ Siltic Aric Colluvic Drainic Duric Dystric/ Eutric Fractic Humic/ Ochric Magnesic Novic Oxyaquic Posic Raptic Technic Toxic Transportic Vetic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *nitic* horizon starting ≤ 100 cm from the soil surface; *and* 2. no *petroplinthic*, *pisoplinthic*, *plinthic* or *vertic* horizon starting ≤ 100 cm from the soil surface; *and* 3. no layers with *reducing conditions* above or within the *nitic* horizon. **NITISOLS**	Ferralic/ Sideralic Ferritic Rhodic Hydragric/ Anthraquic/ Pretic Mollic/ Umbric Acric/ Lixic/ Alic/ Luvic Geric Dystric/ Eutric	Andic Aric Colluvic Densic Ferric Endogleyic Humic/ Ochric Magnesic Novic Oxyaquic Posic Raptic Sodic Endostagnic Technic Toxic Transportic Vetic

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	**Nitisols**	**97**	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *ferralic* horizon starting ≤ 150 cm from the soil surface; *and* 2. no *argic* horizon starting at the upper limit of the *ferralic* horizon or above the *ferralic* hroizon, unless the *argic* horizon has, in its upper 30 cm, one or more of the following: a. < 10% water-dispersible clay; *or* b. *geric* properties; *or* c. ≥ 1.4% *soil organic carbon*. **FERRALSOLS**	Ferritic Gibbsic Petroplinthic/ Pisoplinthic/ Plinthic Rhodic/ Xanthic Pretic Folic Mollic/ Umbric Acric/ Lixic Fractic Skeletic Geric Haplic	Andic Arenic/ Clayic/ Loamic/ Siltic Aric Colluvic Densic Dystric/ Eutric Ferric Fluvic Gleyic Humic/ Ochric Novic Oxyaquic Posic Raptic Sombric Stagnic Technic Toxic Transportic Vetic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having an *abrupt textural difference* ≤ 100 cm from the mineral soil surface; and directly above or below, a layer ≥ 5 cm thick, that has: 1. *stagnic* properties in which the area of reductimorphic colours plus the area of oximorphic colours is ≥ 50% of the layer's total area; *and* 2. *reducing conditions* for some time during the year in the major part of the layer's volume that has the reductimorphic colours. **PLANOSOLS**	Reductic Thionic Fragic Leptic Hydragric/ Anthraquic Folic/ Histic Chernic/ Mollic/ Umbric Gleyic Albic Fluvic Columnic Vertic Glossic/ Retic Acric/ Lixic/ Alic/ Luvic Petroduric/ Duric Calcic Dolomitic/ Calcaric Dystric/ Eutric	Alcalic Arenic/ Clayic/ Loamic/ Siltic Aric Capillaric Chromic Colluvic Densic Drainic Ferralic/ Sideralic Ferric Gelic Gelistagnic Geric Humic/ Ochric Inclinic Magnesic Nechic Novic Plinthic Raptic Skeletic Sodic Sulfidic Technic Toxic Transportic Turbic

Overview of Key to Reference Soil Groups

Histosols	85	Solonchaks	92	**Planosols**	**99**	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having a layer starting ≤ 25 cm from the mineral soil surface, that is ≥ 50 cm thick or ≥ 25 cm thick and directly overlies *continuous rock* or *technic hard* material and that has: 1. *stagnic* properties in which the area of reductimorphic colours plus the area of oximorphic colours is ≥ 50% of the layer's total area; *and* 2. *reducing conditions* for some time during the year in the major part of the layer's volume that has the reductimorphic colours. **STAGNOSOLS**	Reductic Thionic Fragic Leptic Hydragric/ Anthraquic Folic/ Histic Mollic/ Umbric Gleyic Albic Fluvic Vertic Glossic/ Retic Acric/ Lixic/ Alic/ Luvic Calcic Dolomitic/ Calcaric Dystric/ Eutric	Alcalic Arenic/ Clayic/ Loamic/ Siltic Aric Capillaric Colluvic Drainic Ferralic/ Sideralic Ferric Gelic Gelistagnic Geric Humic/ Ochric Inclinic Magnesic Nechic Nitic Novic Ornithic Placic Plinthic Raptic Rhodic/ Chromic Skeletic Sodic Protospodic Sulfidic Technic Toxic Transportic Turbic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *chernic* horizon; *and* 2. a *calcic* horizon or a layer with *protocalcic* properties starting ≤ 50 cm below the lower limit of the *mollic*[c] horizon, and if present, above a cemented or indurated layer; *and* 3. a base saturation (by 1 M NH4OAc, pH 7) of ≥ 50% from the soil surface to the *calcic* horizon or the layer with *protocalcic* properties, throughout. **CHERNOZEMS**	Petroduric/ Duric Petrogypsic/ Gypsic Petrocalcic/ Calcic Leptic Hortic Gleyic Fluvic Vertic Greyzemic Luvic Fractic Skeletic Vermic Haplic	Andic Arenic/ Clayic/ Loamic/ Siltic Aric Cambic Colluvic Densic Hyperhumic Novic Oxyaquic Pachic Raptic Endosalic Sodic Stagnic Technic Tephric Tonguic Transportic Turbic Vitric

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	**Chernozems**	**101**	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

c Any *chernic* horizon also meets the criteria of a *mollic* horizon. The *mollic* horizon may extend below the *chernic* horizon.

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *mollic* horizon; *and* 2. a *calcic* horizon or a layer with *protocalcic* properties starting ≤ 50 cm below the lower limit of the *mollic* horizon, and if present, above a cemented or indurated layer; *and* 3. a base saturation (by 1 M NH4OAc, pH 7) of ≥ 50% from the soil surface to the *calcic* horizon or the layer with *protocalcic* properties, throughout. **KASTANOZEMS**	Someric Petroduric/ Duric Petrogypsic/ Gypsic Petrocalcic/ Calcic Leptic Hortic/ Terric Gleyic Fluvic Vertic Greyzemic Luvic Fractic Skeletic Vermic Haplic	Andic Anthric Arenic/ Clayic/ Loamic/ Siltic Aric Cambic Chromic Colluvic Densic Hyperhumic Novic Oxyaquic Pachic Raptic Endosalic Sodic Stagnic Technic Tephric Tonguic Transportic Turbic Vitric

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having:	Rendzic	Abruptic
1. a *mollic* horizon; *and*	Chernic/ Someric	Albic
2. a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 50% throughout to a depth of 100 cm from the soil surface or to *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower.	Petroduric/ Duric	Andic
	Petrogypsic	Anthric
	Petrocalcic/ Endocalcic	Arenic/ Clayic/ Loamic/ Siltic
	Leptic	Aric
PHAEOZEMS	Irragric/ Hortic/ Pretic/ Terric	Colluvic
	Folic	Columnic
	Gleyic	Densic
	Stagnic	Ferralic/ Sideralic
	Fluvic	Hyperhumic
	Vertic	Isolatic
	Greyzemic	Nechic
	Glossic/ Retic	Novic
	Luvic	Oxyaquic
	Cambic	Pachic
	Fractic	Raptic
	Skeletic	Relocatic
	Vermic	Rhodic/ Chromic
	Gypsiric	Endosalic
	Dolomitic/ Calcaric	Sodic
	Haplic	Technic
		Tephric
		Tonguic
		Transportic
		Turbic
		Vitric

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having an *umbric* or *mollic* or *hortic* horizon. **UMBRISOLS**	Chernic/ Someric Fragic Leptic Hortic/ Plaggic/ Pretic/ Terric Mollic Folic/ Histic Gleyic Stagnic Fluvic Greyzemic Glossic/ Retic Acric/ Lixic/ Alic/ Luvic Cambic/ Brunic Skeletic Endodolomitic/ Endocalcaric Haplic	Abruptic Albic Andic Anthric Arenic/ Clayic/ Loamic/ Siltic Aric Colluvic Densic Drainic Hyperdystric/ Endoeutric Ferralic/ Sideralic Gelic Hyperhumic Isolatic Lamellic Laxic Nechic Novic Ornithic Oxyaquic Pachic Placic Raptic Relocatic Rhodic/ Chromic Protospodic Sulfidic Technic Thionic Tonguic Toxic Transportic Turbic Vitric

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having a *petroduric* or *duric* horizon starting ≤ 100 cm from the soil surface. **DURISOLS**	Petric Petrogypsic/ Gypsic Petrocalcic/ Calcic Leptic Acric/ Lixic/ Alic/ Luvic Hyperskeletic/ Skeletic Dystric/ Eutric	Albic Arenic/ Clayic/ Loamic/ Siltic Aric Chromic Fractic Gleyic Novic Ochric Raptic Endosalic Sodic Stagnic Takyric/ Yermic/ Aridic Technic Toxic Transportic Vertic

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	**Durisols**	**105**	Luvisols	112		

<table>
<tr><th>Key to the Reference Soil Groups</th><th>Principal qualifiers</th><th>Supplementary qualifiers</th></tr>
<tr><td>Other soils having:
1. a petrogypsic horizon starting ≤ 100 cm from the soil surface; or
2. both of the following:
a. a gypsic horizon starting ≤ 100 cm from the soil surface; and
b. no argic horizon above the gypsic horizon unless the argic horizon is permeated with secondary gypsum or secondary carbonate, throughout.

GYPSISOLS</td><td>Petric
Petrocalcic/ Calcic
Leptic
Lixic/ Luvic
Hyperskeletic/ Skeletic
Haplic</td><td>Albic
Arenic/ Clayic/ Loamic/ Siltic
Aric
Arzic
Fluvic
Fractic
Gleyic
Hypergypsic/ Hypogypsic
Novic
Ochric
Raptic
Endosalic
Sodic
Stagnic
Takyric/ Yermic/ Aridic
Technic
Toxic
Transportic
Turbic
Vertic</td></tr>
</table>

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *petrocalcic* horizon starting ≤ 100 cm from the soil surface; *or* 2. both of the following: a. a *calcic* horizon starting ≤ 100 cm from the soil surface; *and* b. no *argic* horizon above the *calcic* horizon unless the *argic* horizon is permeated throughout with secondary carbonate. **CALCISOLS**	Petric Leptic Gypsic Lixic/ Luvic Cambic Hyperskeletic/ Skeletic Haplic	Albic Arenic/ Clayic/ Loamic/ Siltic Aric Hypercalcic/ Hypocalcic Densic Fluvic Fractic Gleyic Novic Ochric Raptic Rhodic/ Chromic Endosalic Sodic Stagnic Takyric/ Yermic/ Aridic Technic Toxic Transportic Turbic Vertic

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	**Calcisols**	**107**	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having an *argic* horizon that starts ≤ 100 cm from the soil surface and has *retic* properties at its upper boundary. **RETISOLS**	Fragic Glossic Leptic Plaggic / Pretic/ Terric Folic/ Histic Gleyic Stagnic Sideralic Nudiargic Neocambic Albic Skeletic Endodolomitic/ Endocalcaric Dystric/ Eutric	Abruptic Arenic/ Clayic/ Loamic/ Siltic Aric Colluvic Cutanic Densic Differentic Drainic Gelic Humic/ Ochric Nechic Novic Oxyaquic Profondic Raptic Protospodic Technic Toxic Transportic Turbic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. an *argic* horizon starting ≤ 100 cm from the soil surface; *and* 2. a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay in some part of the the *argic* horizon within ≤ 50 cm below its upper limit; *and* 3. an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of < 50%: a. in half or more of the part between 50 and 100 cm from the mineral soil surface; *or* b. at least in the lower half of the mineral soil above *continuous rock*, *technic hard* material or a cemented or indurated layer starting ≤ 100 cm from the mineral soil surface. **ACRISOLS**	Abruptic Fragic Leptic Petroplinthic/ Pisoplinthic/ Plinthic Hydragric/ Anthraquic/ Pretic/ Terric Gleyic Stagnic Ferralic Nudiargic Lamellic Albic Ferric Rhodic/ Chromic/ Xanthic Fractic Skeletic Haplic	Andic Arenic/ Clayic/ Loamic/ Siltic Aric Neocambic Colluvic Cutanic Densic Differentic Hyperdystric/ Epieutric Gibbsic Humic/ Ochric Magnesic Nechic Nitic Novic Oxyaquic Profondic Raptic Sombric Technic Toxic Transportic Vetic Vitric

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	**Acrisols**	**109**	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. an *argic* horizon starting ≤ 100 cm from the soil surface; *and* 2. a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay in some part of the the *argic* horizon within ≤ 50 cm below its upper limit. **LIXISOLS**	Abruptic Fragic Leptic Petroplinthic/ Pisoplinthic/ Plinthic Hydragric/ Anthraquic/ Pretic/ Terric Gleyic Stagnic Ferralic Nudiargic Lamellic Albic Ferric Rhodic/ Chromic/ Xanthic Gypsic Calcic Fractic Skeletic Haplic	Andic Arenic/ Clayic/ Loamic/ Siltic Aric Aridic Neocambic Colluvic Cutanic Densic Differentic Epidystric/ Hypereutric Gibbsic Humic/ Ochric Magnesic Nechic Nitic Novic Oxyaquic Profondic Raptic Sodic Technic Toxic Transportic Vetic Vitric

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. an *argic* horizon starting ≤ 100 cm from the soil surface; *and* 2. an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of < 50%: a. in half or more of the part between 50 and 100 cm from the mineral soil surface; *or* b. at least in the lower half of the mineral soil above *continuous rock*, *technic hard* material or a cemented or indurated layer starting ≤ 100 cm from the mineral soil surface. **ALISOLS**	Abruptic Fragic Leptic Petroplinthic/ Pisoplinthic/ Plinthic Hydragric/ Anthraquic/ Plaggic/ Pretic/ Terric Gleyic Stagnic Vertic Nudiargic Lamellic Albic Ferric Rhodic/ Chromic Fractic Skeletic Haplic	Andic Arenic/ Clayic/ Loamic/ Siltic Aric Neocambic Colluvic Cutanic Densic Differentic Hyperdystric/ Epieutric Fluvic Gelic Humic/ Ochric Hyperalic Magnesic Nechic Nitic Novic Oxyaquic Profondic Raptic Protospodic Technic Toxic Transportic Turbic Vitric

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	**Alisols**	**111**		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having an *argic* horizon starting ≤ 100 cm from the soil surface. **LUVISOLS**	Abruptic Fragic Leptic Petroplinthic/ Pisoplinthic/ Plinthic Hydragric/ Anthraquic/ Irragric/ Pretic/ Terric Gleyic Stagnic Vertic Nudiargic Lamellic Albic Ferric Rhodic/ Chromic Gypsic Calcic Fractic Skeletic Endodolomitic/ Endocalcaric Haplic	Andic Arenic/ Clayic/ Loamic/ Siltic Aric Aridic Neocambic Colluvic Cutanic Densic Differentic Epidystric/ Hypereutric Escalic Fluvic Gelic Humic/ Ochric Magnesic Nechic Nitic Novic Oxyaquic Profondic Raptic Sodic Technic Toxic Transportic Turbic Vitric

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having:	Fragic	Geoabruptic
1. a *cambic* horizon	Thionic	Alcalic
a. starting ≤ 50 cm from the soil surface; *and*	Leptic	Arenic/Clayic/ Loamic/ Siltic
b. having its lower limit ≥ 25 cm from the soil surface; *or*	Petroplinthic/ Pisoplinthic/ Plinthic	Aric
2. an *anthraquic*, *hydragric*, *irragric*, *plaggic, pretic* or *terric* horizon; *or*	Hydragric/ Anthraquic/ Irragric/ Plaggic/ Pretic/ Terric	Protocalcic
3. a *fragic*, *petroplinthic*, *pisoplinthic*, *plinthic*, *salic, thionic* or *vertic* horizon starting ≤ 100 cm from the soil surface; *or*	Folic/ Histic	Colluvic
4. one or more layers with *andic* or *vitric* properties with a combined thickness of ≥ 15 cm within ≤ 100 cm of the soil surface.	Gleyic	Densic
CAMBISOLS	Stagnic	Drainic
	Fluvic	Escalic
	Vertic	Ferric
	Andic	Gelic
	Vitric	Gelistagnic
	Ferralic/ Sideralic	Humic/ Ochric
	Rhodic/ Chromic/ Xanthic	Laxic
	Fractic	Magnesic
	Skeletic	Nechic
	Salic	Novic
	Sodic	Ornithic
	Gypsiric	Oxyaquic
	Dolomitic/ Calcaric	Raptic
	Dystric/ Eutric	Protospodic
		Sulfidic
		Takyric/ Yermic/ Aridic
		Technic
		Tephric
		Toxic
		Transportic
		Turbic

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	**Cambisols**	**113**
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	Fluvisols	115
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a weighted average texture class of loamy sand or coarser, if layers of finer texture have a combined thickness of < 15 cm, to a depth of 100 cm from the mineral soil surface; *and* 2. < 40% (by volume) of coarse fragments in all layers within ≤ 100 cm of the mineral soil surface. **ARENOSOLS**[d]	Subaquatic/ Tidalic Folic Gleyic Sideralic Protoargic Brunic Albic Rhodic/ Chromic/ Rubic Lamellic Endosalic Sodic Fluvic Protic Gypsiric Dolomitic/ Calcaric Dystric/ Eutric	Geoabruptic Aeolic Alcalic Aric Protocalcic Colluvic Gelic Humic/ Ochric Hydrophobic Nechic Novic Ornithic Oxyaquic Petrogleyic Placic Raptic Relocatic Protospodic Stagnic Sulfidic Technic Tephric Toxic Transportic Turbic Yermic/ Aridic

d Arenosols may have diagnostic horizons at depths of > 100 cm. These can be indicated with the Bathy- specifier followed by a qualifier, e.g. Bathyacric (> 100 cm), Bathyspodic (> 200 cm).

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having *fluvic* material: 1. ≥ 25 cm thick and starting ≤ 25 cm from the mineral soil surface; *or* 2. from the lower limit of a plough layer that is ≤ 40 cm thick, to a depth of ≥ 50 cm from the mineral soil surface. **FLUVISOLS**[e]	Subaquatic/ Tidalic Pantofluvic/ Anofluvic/ Orthofluvic Leptic Folic/ Histic Gleyic Stagnic Skeletic Sodic Gypsiric Dolomitic/ Calcaric Dystric/ Eutric	Geoabruptic Alcalic Arenic/ Clayic/ Loamic/ Siltic Aric Protocalcic Densic Drainic Gelic Humic/ Ochric Limnic Magnesic Nechic Oxyaquic Petrogleyic Sideralic Sulfidic Takyric/ Yermic/ Aridic Technic Toxic Transportic Turbic Protovertic

Overview of Key to Reference Soil Groups									
Histosols	85	Solonchaks	92	Planosols	99	Gypsisols	106	Cambisols	113
Anthrosols	86	Gleysols	93	Stagnosols	100	Calcisols	107	Arenosols	114
Technosols	87	Andosols	94	Chernozems	101	Retisols	108	**Fluvisols**	**115**
Cryosols	88	Podzols	95	Kastanozems	102	Acrisols	109	Regosols	116
Leptosols	89	Plinthosols	96	Phaeozems	103	Lixisols	110		
Solonetz	90	Nitisols	97	Umbrisols	104	Alisols	111		
Vertisols	91	Ferralsols	98	Durisols	105	Luvisols	112		

e Buried soils occur frequently in this RSG and can be indicated with “over”. Buried diagnostic horizons can be indicated with the Thapto- specifier followed by a qualifier.

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils: **REGOSOLS**	Leptic Folic Gleyic Stagnic Skeletic Brunic Colluvic Tephric Endosalic Sodic Protic Vermic Gypsiric Dolomitic/ Calcaric Dystric/ Eutric	Geoabruptic Aeolic Alcalic Arenic/ Clayic/ Loamic/ Siltic Aric Protocalcic Densic Drainic Escalic Fluvic Gelic Gelistagnic Humic/ Ochric Isolatic Lamellic Magnesic Nechic Ornithic Oxyaquic Raptic Relocatic Takyric/ Yermic/ Aridic Technic Toxic Transportic Turbic Protovertic

Chapter 5
Definitions of qualifiers

Before using the qualifiers, please read the 'Rules for classifying soils' (Chapter 2).

The definitions of the qualifiers for the second-level units relate to RSGs, diagnostic horizons, properties and materials, attributes such as colour, chemical conditions, texture, etc. References to the RSGs defined in Chapter 4 and the diagnostic features listed in Chapter 3 are shown *italics*.

Usually, only a limited number of combinations will be possible; many of the definitions make the qualifiers mutually exclusive.

Subqualifiers (see Chapter 2.4) that may be used in the soil name instead of the qualifier listed in the Key (Chapter 4), are found beneath the definition of the respective qualifier (e.g. Protocalcic is found under Calcic). Subqualifiers that cannot replace a listed qualifier are found in alphabetical order (e.g. Hyperalic). If a subqualifier related to depth requirements (optional or additional subqualifiers) can be constructed, the figure indicates, which rule applies: (1), (2), (3), (4), (5). If no figure is indicated, these subqualifiers cannot be constructed.

Abruptic (ap) (from Latin *abruptus*, broken away): having an *abrupt textural difference* within ≤ 100 cm of the mineral soil surface (1).

Geoabruptic (go) (from Greek *gaia*, earth): having an *abrupt textural difference* within ≤ 100 cm of the mineral soil surface that is not associated with the upper limit of an *argic* or *natric* horizon (1).

Aceric (ae) (from Latin *acer*, sharp): having within ≤ 100 cm of the soil surface a layer with a pH (1:1 in water) between ≥ 3.5 and < 5 and jarosite mottles (*in Solonchaks only*) (2).

Acric (ac) (from Latin *acer*, sharp): having an *argic* horizon starting ≤ 100 cm from the soil surface and having a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay in some part ≤ 50 cm below its upper limit; and having an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of < 50% in half or more of the part between 50 and 100 cm from the mineral soil surface *or* in the lower half of the mineral soil above *continuous rock*, *technic hard* material or a cemented or indurated layer starting ≤ 100 cm from the mineral soil surface, whichever is shallower (2).

Acroxic (ao) (from Latin *acer*, sharp, and Greek *oxys*, sour): having within ≤ 100 cm of the soil surface one or more layers with a combined thickness of ≥ 30 cm, and with < 2 $cmol_c$ kg^{-1} fine earth exchangeable bases (by 1 *M* NH_4OAc, pH 7) plus exchangeable Al (by 1 *M* KCl, unbuffered) (*in Andosols only*) (2).

Aeolic (ay) (from Greek *aiolos*, wind): having at the soil surface a layer, ≥ 10 cm thick, the material of which is deposited by wind and has < 0.6% *soil organic carbon* (2: Ano- and Panto- only).

Albic (ab) (from Latin *albus*, white): having a layer of *albic* material ≥ 1 cm thick, and starting ≤ 100 cm from the mineral soil surface, that does not consist of *tephric* material, does not contain carbonates, and does not contain gypsum; and that overlies a diagnostic horizon or forms part of a layer with *stagnic* properties (2).

Alcalic (ax) (from Arabic *al-qali*, salt-containing ash): having:
- a pH (1:1 in water) of ≥ 8.5 throughout within ≤ 50 cm of the mineral soil surface, or to *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower, *and*
- an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of ≥ 50%:
  - in the major part between 20 and 100 cm from the mineral soil surface *or*
  - in the major part between 20 cm and *continuous rock*, *technic hard* material or a cemented or indurated layer starting > 25 cm from the mineral soil surface, *or*
  - in a layer ≥ 5 cm thick, directly above *continuous rock*, *technic hard* material or a cemented or indurated layer starting ≤ 25 cm from the mineral soil surface.

Alic (al) (from Latin *alumen*, alum): having an *argic* horizon starting ≤ 100 cm from the soil surface and having a CEC (by 1 *M* NH_4OAc, pH 7) of ≥ 24 $cmol_c$ kg^{-1} clay throughout or to a depth of 50 cm of its upper limit, whichever is thinner; and having an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of < 50% in half or more of the part between 50 and 100 cm from the mineral soil surface *or* in the lower half of the mineral soil above *continuous rock*, *technic hard* material or a cemented or indurated layer starting ≤ 100 cm from the mineral soil surface, whichever is shallower (2).

Aluandic (aa) (from Latin *alumen*, alum, and Japanese *an*, dark, and *do*, soil): having within ≤ 100 cm of the soil surface one or more layers with a combined thickness of ≥ 15 cm with *andic* properties and a Si_{ox} content of < 0.6% and an Al_{py}/Al_{ox} of ≥ 0.5 (*in Andosols only*) (2).

Andic (an) (from Japanese *an*, dark, and *do*, soil): having within ≤ 100 cm of the soil surface one or more layers with *andic* or *vitric* properties with a combined thickness of ≥ 30 cm (in *Cambisols* ≥ 15 cm), of which ≥ 15 cm (in *Cambisols* ≥ 7.5 cm) have *andic* properties (2).

Protoandic (qa) (from Greek *protou*, before): having within ≤ 100 cm of the soil surface one or more layers with a combined thickness of ≥ 15 cm, and with an Al_{ox} + ½Fe_{ox} value of ≥ 1.2%, a bulk density[23] of ≤ 1 kg dm^{-3} and a phosphate retention of ≥ 55%; and not fulfilling the set of criteria of the Andic qualifier (2).

Anthraquic (aq) (from Greek *anthropos*, human being, and Latin *aqua*, water): having an *anthraquic* horizon and no *hydragric* horizon.

[23] For bulk density, the volume is determined after an undried soil sample has been desorbed at 33 kPa (no prior drying), and afterwards the weight is determined oven-dried (see Annex 2).

Anthric (ak) (from Greek *anthropos*, human being): having *anthric* properties.

Archaic (ah) (from Greek *archae*, beginning): having a layer ≥ 20 cm thick, within ≤ 100 cm of the soil surface, with ≥ 20% (by volume, weighted average) *artefacts* containing ≥ 50% (by volume) *artefacts* produced by pre-industrial processes, e.g. ceramics, showing traces of production by hand, ceramics that can easily be broken or ceramics containing sand (*in Technosols* only) (2).

Arenic (ar) (from Latin *arena*, sand): having a texture class of sand or loamy sand in a layer ≥ 30 cm thick, within ≤ 100 cm of the mineral soil surface or in the major part between the mineral soil surface and *continuous rock, technic hard* material or a cemented or indurated layer starting < 60 cm from the mineral soil surface starting < 60 cm from the mineral soil surface (2; no subqualifier if *continuous rock* or *technic hard* material starts < 60 cm from the mineral soil surface).

Aric (ai) (from Latin *arare*, to plough): being ploughed to a depth of ≥ 20 cm from the soil surface (2: Ano- and Panto- only).

Aridic (ad) (from Latin *aridus*, dry): having *aridic* properties without *takyric* or *yermic* properties.

Protoaridic (qd) (from Greek *protou*, before): having a mineral topsoil layer ≥ 5 cm thick, with a Munsell colour value, dry, of ≥ 5 that turns darker on moistening; < 0.4% *soil organic carbon*, a platy structure in ≥ 50% of the volume, a surface crust; and not having *aridic* properties.

Arzic (az) (from Turkish *arz*, land or earth's crust): having sulfate-rich groundwater in some layer within ≤ 50 cm of the soil surface during some time in most years and containing ≥ 15% (by volume) gypsum averaged over a depth of 100 cm from the soil surface or to *continuous rock*, *technic hard* material or a cemented or indurated layer, whichever is shallower (*in Gypsisols only*).

Brunic (br) (from Low German *brun*, brown): having a layer ≥ 15 cm thick, and starting ≤ 50 cm from the soil surface, that meets diagnostic criteria 2–4 of the *cambic* horizon but fails diagnostic criterion 1, and does not consist of *albic* material.

Calcaric (ca) (from Latin *calcarius*, containing lime): having *calcaric* material throughout between 20 and 100 cm from the soil surface, or between 20 cm and *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower; and not having a *calcic* or a *petrocalcic* horizon starting ≤ 100 cm from the soil surface (4).

Calcic (cc) (from Latin *calx*, lime): having a *calcic* horizon starting ≤ 100 cm from the soil surface (2).

Hypercalcic (jc) (from Greek *hyper*, over): having a *calcic* horizon with a calcium carbonate equivalent in the fine earth fraction of ≥ 50% (by mass) and starting ≤ 100 cm from the soil surface (2).

Hypocalcic (wc) (from Greek *hypo*, under): having a *calcic* horizon with a calcium carbonate equivalent in the fine earth fraction of < 25% (by mass) and starting ≤ 100 cm from the soil surface (2).

Protocalcic (qc) (from Greek *protou*, before): having a layer with *protocalcic* properties starting ≤ 100 cm from the soil surface and not having a *calcic* or *petrocalcic* horizon starting ≤ 100 cm from the soil surface (2).

Cambic (cm) (from Late Latin *cambiare*, to change): having a *cambic* horizon not consisting of *albic* material and starting ≤ 50 cm from the soil surface.

Neocambic (nc) (from Greek *neos*, new): having a *cambic* horizon, not consisting of *albic* material, starting ≤ 50 cm from the soil surface and overlying:
- *albic* material that overlies an *argic*, a *natric* or a *spodic* horizon, *or*
- a layer with *retic* properties.

Capillaric (cp) (from Latin *capillus*, hair): having a layer ≥ 25 cm thick that has so few macropores that water saturation of capillary pores causes *reducing conditions* (2).

Carbic (cb) (from Latin *carbo*, coal): having a *spodic* horizon that does not turn redder on ignition throughout (*in Podzols only*).

Carbonatic (cn) (from Latin *carbo*, coal): having a *salic* horizon with a soil solution (1:1 in water) with a pH of ≥ 8.5 and $[HCO_3^-] > [SO_4^{2-}] > 2*[Cl^-]$ (*in Solonchaks only*).

Carbonic (cx) (from Latin *carbo*, coal): having a layer ≥ 10 cm thick, and starting ≤ 100 cm from the soil surface, with ≥ 20% (by mass) organic carbon that meets the diagnostic criteria of *artefacts* (2).

Chernic (ch) (from Russian *chorniy*, black)**:** having a *chernic* horizon (2: Ano- and Panto- only).

Tonguichernic (tc) (from English *tongue*): having a *chernic* horizon that tongues into an underlying layer (2: Ano- and Panto- only).

Chloridic (cl) (from Greek *chloros*, yellow-green): having a *salic* horizon with a soil solution (1:1 in water) with $[Cl^-] > 2*[SO_4^{2-}] > 2*[HCO_3^-]$ (*in Solonchaks only*).

Chromic (cr) (from Greek *chroma*, colour): having between 25 and 150 cm of the soil surface a layer, ≥ 30 cm thick, that has, in ≥ 90% of its exposed area, a Munsell colour hue redder than 7.5YR and a chroma of > 4, both moist (2: except Epi-).

Clayic (ce) (from English *clay*): having a texture class of clay, sandy clay or silty clay, in a layer ≥ 30 cm thick, within ≤ 100 cm of the mineral soil surface or in the major part between the mineral soil surface and *continuous rock, technic hard* material or a cemented or indurated layer starting < 60 cm from the mineral soil surface (2; no subqualifier if *continuous rock* or *technic hard* material starts < 60 cm from the mineral soil surface).

Colluvic (co) (from Latin *colluvio*, mixture): having *colluvic* material ≥ 20 cm thick, and starting at the mineral soil surface (2: Ano- and Panto- only).

Columnic (cu) (from Latin *columna*, column): having a layer ≥ 15 cm thick, and starting ≤ 100 cm from the soil surface, that has a columnar structure (2).

Cryic (cy) (from Greek *kryos*, cold, ice): having a *cryic* horizon starting ≤ 100 cm from the soil surface, or having a *cryic* horizon starting ≤ 200 cm from the soil surface with evidence of cryoturbation in some layer ≤ 100 cm from the soil surface (1; Epi- and Endo- only; referring to the upper limit of the *cryic* horizon).

Cutanic (ct) (from Latin *cutis*, skin): having an *argic* or *natric* horizon that meets diagnostic criterion 2b for the respective horizon.

Densic (dn) (from Latin *densus*, dense): having natural or artificial compaction ≤ 100 cm from the soil surface to the extent that roots cannot penetrate, or can only penetrate it with severe difficulty (2).

Differentic (df) (from Latin *differentia*, difference): having an *argic* or *natric* horizon that meets diagnostic criterion 2a for the respective horizon.

Dolomitic (do) (from the mineral dolomite, named after the French geoscientist *Déodat de Dolomieu*): having *dolomitic* material throughout between 20 and 100 cm from the soil surface or between 20 cm and *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower (4).

Drainic (dr) (from French *drainer*, to drain): having artificial drainage.

Duric (du) (from Latin *durus*, hard): having a *duric* horizon starting ≤ 100 cm from the soil surface (2).

Hyperduric (ju) (from Greek *hyper*, over): having a *duric* horizon with ≥ 50% (by volume) durinodes or fragments of a broken-up *petroduric* horizon starting ≤ 100 cm from the soil surface (2).

Dystric (dy) (from Greek *dys*, bad, and *trophae*, food): having:

- in *Histosols*, a pH_{water} < 5.5 in half or more of the part with *organic* material, within 100 cm of the soil surface,
- in other soils, an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of < 50%:
  * in half or more of the part between 20 and 100 cm from the mineral soil surface, *or*
  * in half or more of the part between 20 cm from the mineral soil surface and *continuous rock*, *technic hard* material or a cemented or indurated layer starting > 25 cm from the mineral soil surface, *or*
  * in a layer ≥ 5 cm thick, directly above *continuous rock*, *technic hard* material or a cemented or indurated layer starting ≤ 25 cm from the mineral soil surface (3).

Hyperdystric (jd) (from Greek *hyper*, over): having:

- in *Histosols*, a pH_{water} < 5.5 throughout in the *organic* material within 100 cm of the soil surface and <4.5 in some layer with *organic* material within ≤ 100 cm of the soil surface,
- in other soils, an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of < 50% throughout between 20 and 100 cm from the mineral soil surface, and < 20% in some layer between 20 and 100 cm from the mineral soil surface.

Orthodystric (od) (from Greek *orthos*, right): having:

- in *Histosols*, a pH_{water} < 5.5 throughout in the *organic* material within 100 cm of the soil surface,
- in other soils, an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc

(pH 7), exchangeable Al by 1 M KCl (unbuffered)] of < 50% throughout between 20 and 100 cm from the mineral soil surface.

Ekranic (ek) (from French *écran*, shield): having *technic hard* material starting ≤ 5 cm from the soil surface (*in Technosols only*).

Entic (et) (from Latin *recens*, young): having a loose *spodic* horizon and not having a layer with *albic* material (*in Podzols only*).

Escalic (ec) (from Spanish *escala*, terrace): occurring in human-made terraces.

Eutric (eu) (from Greek *eu*, good, and *trophae*, food): having:

- in *Histosols*, a pH_{water} ≥ 5.5 in the major part with *organic* material, within 100 cm of the soil surface,
- in other soils, an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of ≥ 50%:
  - * in the major part between 20 and 100 cm from the mineral soil surface, *or*
  - * in the major part between 20 cm from the mineral soil surface and *continuous rock*, *technic hard* material or a cemented or indurated layer starting > 25 cm from the mineral soil surface, *or*
  - * in a layer ≥ 5 cm thick, directly above *continuous rock*, *technic hard* material or a cemented or indurated layer starting ≤ 25 cm from the mineral soil surface (3).

Hypereutric (je) (from Greek *hyper*, over): having:

- in *Histosols*, a pH_{water} ≥ 5.5 throughout in the *organic* material within 100 cm of the soil surface and ≥ 6.5 in some layer with *organic* material within ≤ 100 cm of the soil surface,
- in other soils, an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of ≥ 50% throughout between 20 and 100 cm from the mineral soil surface, and ≥ 80% in some layer between 20 and 100 cm from the mineral soil surface.

Oligeoeutric (ol) (from Greek *oligos*, few): having an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of ≥ 50% and a sum of exchangeable bases of < 5 $cmol_c\ kg^{-1}$ clay:

- * in the major part between 20 and 100 cm from the mineral soil surface, *or*
- * in the major part between 20 cm from the mineral soil surface and *continuous rock*, *technic hard* material or a cemented or indurated layer starting > 25 cm from the mineral soil surface, *or*
- * in a layer ≥ 5 cm thick, directly above *continuous rock*, *technic hard* material or a cemented or indurated layer starting ≤ 25 cm from the mineral soil surface (3).

Orthoeutric (oe) (from Greek *orthos*, right): having:

- in *Histosols*, a pH_{water} ≥ 5.5 throughout in the *organic* material within 100 cm of the soil surface,
- in other soils, an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of ≥ 50% throughout between 20 and 100 cm from the mineral soil surface.

Eutrosilic (es) (from Greek *eu*, good, and *trophae*, food, and Latin *silicia*, silicon-containing material): having within ≤ 100 cm of the soil surface one or more layers with a combined thickness of ≥ 30 cm, with *andic* properties and a sum of exchangeable bases (by 1 *M* NH_4OAc, pH 7) of ≥ 15 $cmol_c$ kg^{-1} fine earth (*in Andosols* only) (2).

Evapocrustic (ev) (from Latin *e*, out, and *vapor*, steam, and *crusta*, crust): having a saline crust ≤ 2 cm thick, on the soil surface (*in Solonchaks only*).

Ferralic (fl) (from Latin *ferrum*, iron, and *alumen*, alum): having a *ferralic* horizon starting ≤ 150 cm of the soil surface (2).

Ferric (fr) (from Latin *ferrum*, iron): having a *ferric* horizon starting ≤ 100 cm of the soil surface (2).

Manganiferric (mf) (from Latin *magnesia nigra*, black mineral from the city of Magnesia): having a *ferric* horizon starting ≤ 100 cm from the soil surface in which ≥ 50% of the concretions and/or nodules and/or mottles are black (2).

Ferritic (fe) (from Latin *ferrum*, iron): having a layer ≥ 30 cm thick, and starting ≤ 100 cm from the soil surface, with Fe_{dith} in the fine earth fraction of ≥ 10% and not forming part of a *petroplinthic*, *pisoplinthic* or *plinthic* horizon (2).

Hyperferritic (jf) (from Greek *hyper*, over): having a layer ≥ 30 cm thick, and starting ≤ 100 cm from the soil surface, with Fe_{dith} in the fine earth fraction of ≥ 30% and not forming part of a *petroplinthic*, *pisoplinthic* or *plinthic* horizon (2).

Fibric (fi) (from Latin *fibra*, fiber): having, after rubbing, two-thirds or more (by volume) of the *organic* material consisting of recognizable plant tissue within 100 cm of the soil surface (*in Histosols only*).

Floatic (ft) (from English *to float*): having *organic* material floating on water (*in Histosols only*).

Fluvic (fv) (from Latin *fluvius*, river): having *fluvic* material ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface (2).

Akrofluvic (kf) (from Greek *akra*, top): having *fluvic* material from the mineral soil surface to a depth of ≥ 5 cm, but < 25 cm thick (note: in addition to the Akrofluvic subqualifier, a soil may also have the Amphifluvic, the Katofluvic or the Endofluvic subqualifier).

Orthofluvic (of) (from Greek *orthos*, right): having *fluvic* material:

- from the mineral soil surface to a depth of ≥ 5 cm, *and*
  - ≥ 25 cm thick, and starting ≤ 25 cm from the mineral soil surface, *or*
  - from the lower limit of a plough layer that is ≤ 40 cm thick, to a depth of ≥ 50 cm from the mineral soil surface.

Folic (fo): having a *folic* horizon starting at the soil surface.

Fractic (fc) (from Latin *fractus*, broken): having a layer ≥ 10 cm thick, and starting ≤ 100 cm from the soil surface, consisting of a broken cemented or indurated horizon, the remnants of which:

- occupy a volume of ≥ 40%, *and*
- have an average horizontal length of < 10 cm and/or occupy a volume of < 80% (2).

Calcifractic (cf) (from Latin *calx*, lime): having a layer ≥ 10 cm thick, and starting ≤ 100 cm from the soil surface, consisting of a broken *petrocalcic* horizon, the remnants of which:
- occupy a volume of ≥ 40%, *and*
- have an average horizontal length of < 10 cm and/or occupy a volume of < 80% (2).

Gypsifractic (gf) (from Greek *gypsos*, gypsum): having a layer ≥ 10 cm thick, and starting ≤ 100 cm from the soil surface, consisting of a broken *petrogypsic* horizon, the remnants of which:
- occupy a volume of ≥ 40%, and
- have an average horizontal length of < 10 cm and/or occupy a volume of < 80% (2).

Plinthofractic (pf) (from Greek *plinthos*, brick): having a layer ≥ 10 cm thick, and starting ≤ 100 cm from the soil surface, consisting of a broken *petroplinthic* horizon, the remnants of which:
- occupy a volume of ≥ 40%, and
- have an average horizontal length of < 10 cm and/or occupy a volume < 80% (2).

Fragic (fg) (from Latin *fragilis*, fragile): having a *fragic* horizon starting ≤ 100 cm from the soil surface (2).

Fulvic (fu) (from Latin *fulvus*, dark yellow): having a *fulvic* horizon starting ≤ 30 cm from the soil surface (2: except Endo-).

Garbic (ga) (from English *garbage*): having a layer ≥ 20 cm thick, within ≤ 100 cm of the soil surface, with ≥ 20% (by volume, weighted average) *artefacts* containing ≥ 35% (by volume) organic waste (*in Technosols only*) (2).

Gelic (ge) (from Latin *gelare*, to freeze):
- having a layer with a soil temperature of ≤ 0 °C for ≥ 2 consecutive years, starting ≤ 200 cm from the soil surface, *and*
- not having a *cryic* horizon starting ≤ 100 cm from the soil surface, *and*
- not having a *cryic* horizon starting ≤ 200 cm from the soil surface with evidence of cryoturbation in some layer within ≤ 100 cm of the soil surface (1; Epi- and Endo- only).

Gelistagnic (gt) (from Latin *gelare*, to freeze, and *stagnare*, to stagnate): having temporary water saturation caused by a frozen layer.

Geoabruptic (go): *see Abruptic.*

Geric (gr) (from Greek *geraios*, old): having within ≤ 100 cm of the soil surface a layer with *geric* properties (2).

Gibbsic (gi) (from the mineral gibbsite, named after the US mineralogist *George Gibbs*): having a layer ≥ 30 cm thick, and starting ≤ 100 cm from the soil surface, containing ≥ 25% gibbsite in the fine earth fraction (2).

Gilgaic (gg) (from Aboriginal Australian *gilgai*, water hole): having at the soil surface, microhighs and microlows with a difference in level of ≥ 10 cm, i.e. gilgai microrelief (*in Vertisols only*).

Glacic (gc) (from Latin *glacies*, ice): having a layer ≥ 30 cm thick, and starting ≤ 100 cm from the soil surface, containing ≥ 75% ice (by volume) (2).

Gleyic (gl) (from Russian *gley*, mucky soil mass): having a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface, that has *gleyic* properties throughout and *reducing conditions* in some parts of every sublayer (2).

- **Relictigleyic (rl)** (from Latin *relictus*, left back): having a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface, that has *gleyic* properties throughout and no *reducing conditions* (2).

Glossic (gs) (from Greek *glossa*, tongue)**:** having *albeluvic glossae* starting ≤ 100 cm from the soil surface.

Greyzemic (gz) (from English *grey*, and Russian *zemlya*, earth): having uncoated silt and sand grains on structural faces in the lower half of a *mollic* horizon.

Grumic (gm) (from Latin *grumus*, soil heap): having a soil surface layer ≥ 1 cm thick, with a strong granular structure, coarse (10 mm) or finer, i.e. 'self-mulching' (*in Vertisols only*).

Gypsic (gy) (from Greek *gypsos*, gypsum): having a *gypsic* horizon starting ≤ 100 cm from the soil surface (2).

- **Hypergypsic (jg)** (from Greek *hyper*, over): having a *gypsic* horizon with a gypsum content in the fine earth fraction of ≥ 50% (by mass) and starting ≤ 100 cm from the soil surface (2).
- **Hypogypsic (wg)** (from Greek *hypo*, under): having a *gypsic* horizon with a gypsum content in the fine earth fraction of < 25% (by mass) and starting ≤ 100 cm from the soil surface (2).

Gypsiric (gp) (from Greek *gypsos*, gypsum): having *gypsiric* material throughout between 20 and 100 cm from the soil surface or between 20 cm and *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower; and not having a *gypsic* or *petrogypsic* horizon starting ≤ 100 cm from the soil surface (4).

Haplic (ha) (from Greek *haplous*, simple): having a typical expression of certain features (typical in the sense that there is no further or meaningful characterization) and only used if none of the preceding qualifiers applies.

Hemic (hm) (from Greek *hemisys*, half): having, after rubbing, less than two-thirds and one-sixth or more (by volume) of the *organic* material consisting of recognizable plant tissue within 100 cm of the soil surface (*in Histosols only*).

Histic (hi) (from Greek *histos*, tissue): having a *histic* horizon starting at the soil surface.

Hortic (ht) (from Latin *hortus*, garden): having a *hortic* horizon (2: Panto- only).

Humic (hu) (from Latin *humus*, earth): having ≥ 1% *soil organic carbon* in the fine earth fraction as a weighted average to a depth of 50 cm from the mineral soil surface (if *continuous rock*, *technic hard* material or a cemented or indurated layer starts within the specified depth, the depth range below that contributes a 0 to the calculation).

Hyperhumic (jh) (from Greek *hyper*, over): having ≥ 5% *soil organic carbon* in the fine earth fraction as a weighted average to a depth of 50 cm from the mineral soil surface.

Profundihumic (dh) (from Latin *profundus*, deep): having ≥ 1.4% *soil organic carbon* in the fine earth fraction as a weighted average to a depth of 100 cm from the mineral soil surface.

Hydragric (hg) (from Greek *hydor*, water, and Latin *ager*, field): having an *anthraquic* horizon and a directly underlying *hydragric* horizon, the latter starting ≤ 100 cm from the soil surface.

Hyperhydragric (jy) (from Greek *hyper*, over): having an *anthraquic* horizon and a directly underlying *hydragric* horizon with a combined thickness of ≥ 100 cm.

Hydric (hy) (from Greek *hydor*, water): having within ≤ 100 cm of the soil surface one or more layers with a combined thickness of ≥ 35 cm that have a water content ≥ 100% at 1500 kPa tension, measured without previous drying of the sample (*in Andosols only*) (2).

Hydrophobic (hf) (from Greek *hydor*, water, and *phobos*, fear): water-repellent, i.e. water stands on a dry soil surface for ≥ 60 seconds (*in Arenosols only*).

Hyperalic (jl) (from Greek *hyper*, over, and Latin *alumen*, alum): having an *argic* horizon, starting ≤ 100 cm from the soil surface, that has a silt to clay ratio of < 0.6 and an Al saturation (effective) of ≥ 50%, throughout or to a depth of 50 cm below its upper limit, whichever is thinner (*in Alisols only*).

Hyperartefactic (ja) (from Greek *hyper*, over, and Latin *ars*, art, and *factus*, made): having ≥ 50% (by volume, weighted average) *artefacts* within 100 cm of the soil surface or to *continuous rock*, *technic hard* material or a cemented or indurated layer, whichever is shallower (*in Technosols only*).

Hypercalcic (jc): *see Calcic.*

Hypereutric (je): *see Eutric.*

Hypergypsic (jg): *see Gypsic.*

Hyperhumic (jh): *see Humic.*

Hypernatric (jn): *see Natric.*

Hyperorganic (jo) (from Greek *hyper*, over, and *organon*, tool): having *organic* material ≥ 200 cm thick (*in Histosols only*).

Hypersalic (jz)*: see Salic.*

Hyperskeletic (jk) (from Greek *hyper*, over, and *skeletos*, dried out): having < 20% (by volume) fine earth, averaged over a depth of 75 cm from the soil surface or to *continuous rock*, *technic hard* material or a cemented or indurated layer starting > 25 cm from the soil surface, whichever is shallower.

Hyperspodic (jp): *see Spodic.*

Hypocalcic (wc): *see Calcic.*

Hypogypsic (wg): *see Gypsic.*

Immissic (im) (from Latin *immissus*, sent inside): having at the soil surface a layer ≥ 10 cm thick, with ≥ 20% (by mass) recently sedimented dust, soot or ash that meets the criteria of *artefacts* (2: Ano- and Panto- only).

Inclinic (ic) (from Latin *inclinare*, to bow): having
- a slope inclination of ≥ 5%, *and*
- a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface, with *gleyic* or *stagnic* properties and a subsurface water flow for some time during the year.

Infraandic (ia) (from Latin *infra*, below, and Japanese *an*, dark, and *do*, soil): having a layer ≥ 15 cm thick, that underlies a soil classified with preference according to the 'Rules for classifying soils' (Chapter 2.5) and that meets diagnostic criteria 1 and 3 of the *andic* properties and fails diagnostic criterion 2.

Infraspodic (is) (from Latin *infra*, below, and Greek *spodos*, wood ash): having a layer that underlies a soil classified with preference according to the 'Rules for classifying soils' (Chapter 2.5) and that meets diagnostic criteria 3 to 6 of the *spodic* horizon and fails diagnostic criterion 1 or 2 or both.

Irragric (ir) (from Latin *irrigare*, to irrigate, and *ager*, field): having an *irragric* horizon (2: Panto- only).

Isolatic (il) (from Italian *isola*, island): having, above *technic hard* material, above a geomembrane or above a continuous layer of *artefacts* starting ≤ 100 cm from the soil surface, soil material containing fine earth without any contact to other soil material containing fine earth (e.g. soils on roofs or in pots).

Lamellic (ll): (from Latin *lamella*, metal blade): having two or more lamellae (≥ 0.5 and < 7.5 cm thick) that have higher clay contents than the directly overlying layers as stated in the diagnostic criteria 2.a of the *argic* horizon, with a combined thickness of ≥ 5 cm; the uppermost lamella starting ≤ 100 cm from the soil surface (2).

Totilamellic (ta) (from Latin *totus*, complete): having an *argic* horizon that consists entirely of lamellae starting ≤ 100 cm from the soil surface.

Lapiadic (ld) (from Latin *lapis*, stone): having at the soil surface *continuous rock* that has dissolution features (rills, grooves), ≥ 20 cm deep and covering ≥ 10 and < 50% of the surface of the *continuous rock* (*in Leptosols only*).

Laxic (la) (from Latin *laxus*, slack): having between 25 and 75 cm from the mineral soil surface a mineral soil layer ≥ 20 cm thick, that has a bulk density[24] of ≤ 0.9 kg dm^{-3}.

Leptic (le) (from Greek *leptos*, thin): having *continuous rock* or *technic hard* material starting ≤ 100 cm from the soil surface (1: Epi- and Endo- only).

Technoleptic (tl) (from Greek *technae*, art): having *technic hard* material starting ≤ 100 cm from the soil surface (1: Epi- and Endo- only).

Lignic (lg) (from Latin *lignum*, wood): having inclusions of intact wood fragments that make up ≥ 25% of the soil volume, within 50 cm from the soil surface.

Limnic (lm) (from Greek *limnae*, pool): having one or more layers with *limnic* material with a combined thickness of ≥ 10 cm within ≤ 50 cm of the soil surface.

Linic (lc) (from Latin *linea*, line): having a continuous, very slowly permeable to impermeable constructed geomembrane of any thickness starting ≤ 100 cm from the soil surface (1).

Lithic (li) (from Greek *lithos*, stone): having *continuous rock* or *technic hard* material starting ≤ 10 cm from the soil surface (*in Leptosols only*).

Technolithic (tt) (from Greek *technae*, art): having *technic hard* material starting ≤ 10 cm from the soil surface (*in Leptosols only*).

Nudilithic (nt) (from Latin *nudus*, naked): having *continuous rock* at the surface (*in Leptosols only*).

Lixic (lx) (from Latin *lixivia*, washed-out substances): having an *argic* horizon starting ≤ 100 cm from the soil surface and having a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay in some part ≤ 50 cm below its upper limit; and having an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of ≥ 50% in the major part between 50 and 100 cm from the mineral soil surface *or* in the lower half of the mineral soil above *continuous rock*, *technic hard* material or a cemented or indurated layer starting ≤ 100 cm from the mineral soil surface, whichever is shallower (2).

Loamic (lo) (from English *loam*): having a texture class of loam, sandy loam, sandy clay loam, clay loam or silty clay loam in a layer ≥ 30 cm thick, within ≤ 100 cm of the mineral soil surface or in the major part between the mineral soil surface and *continuous rock, technic hard* material or a cemented or indurated layer starting < 60 cm from the mineral soil surface (2; no subqualifier if *continuous rock* or *technic hard* material starts < 60 cm from the mineral soil surface).

Luvic (lv) (from Latin *eluere*, to wash): having an *argic* horizon starting ≤ 100 cm from the soil surface and having a CEC (by 1 *M* NH_4OAc, pH 7) of ≥ 24 $cmol_c$ kg^{-1} clay throughout or to a depth of 50 cm of its upper limit, whichever is thinner; and having an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1

[24] For bulk density, the volume is determined after an undried soil sample has been desorbed at 33 kPa (no prior drying), and afterwards the weight is determined oven-dried (see Annex 2).

M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of ≥ 50% in the major part between 50 and 100 cm from the mineral soil surface *or* in the lower half of the mineral soil above *continuous rock*, *technic hard* material or a cemented or indurated layer starting ≤ 100 cm from the mineral soil surface, whichever is shallower (2).

Magnesic (mg) (from the chemical element *magnesium* - no agreed etymology): having an exchangeable Ca to Mg ratio of < 1 in the major part within 100 cm of the soil surface or to *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower (3).

Hypermagnesic (jm) (from Greek *hyper*, over): having an exchangeable Ca to Mg ratio of < 0.1 in the major part within 100 cm of the soil surface or to *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower (3).

Mawic (mw): (from Kiswahili *mawe*, stones): having a layer of coarse fragments, the interstices of which are filled with *organic* material, and that is directly overlain by *organic* material (*in Histosols only*) (1: Epi- and Endo- only; referring to the upper limit of the layer of coarse fragments).

Mazic (mz) (from Spanish *maza*, cudgel): massive and hard to very hard in the upper 20 cm of the soil (*in Vertisols only*).

Melanic (ml) (from Greek *melas*, black): having a *melanic* horizon starting ≤ 30 cm from the soil surface (*in Andosols only*) (2: except Endo-).

Mesotrophic (ms) (from Greek *mesos*, middle, and *trophae*, food): having an effective base saturation [exchangeable(Ca + Mg + K + Na) / exchangeable(Ca + Mg + K + Na + Al); exchangeable bases by 1 M NH_4OAc (pH 7), exchangeable Al by 1 M KCl (unbuffered)] of < 75% at a depth of 20 cm from the soil surface (*in Vertisols only*).

Mineralic (mi) (from Celtic *mine*, mineral): having, within ≤ 100 cm of the soil surface, one or more layers of *mineral* material with a combined thickness of ≥ 20 cm, in between layers of *organic* material (*in Histosols only*) (2: Epi-, Endo-, Amphi- and Kato- only).

Akromineralic (km) (from Greek *akra*, top): having *mineral* material, ≥ 5 cm thick, starting at the soil surface, but the layers of *mineral* material above or in between layers of *organic* material have a combined thickness of < 20 cm (*in Histosols only*).

Orthomineralic (oi) (from Greek *orthos*, right): having:

- *mineral* material, ≥ 5 cm thick, starting at the soil surface, *and*
- within ≤ 100 cm of the soil surface, one or more layers of *mineral* material with a combined thickness of ≥ 20 cm, above or in between layers of *organic* material (*in Histosols only*).

Mollic (mo) (from Latin *mollis*, soft): having a *mollic* horizon (2: Ano- and Panto- only).

Anthromollic (am) (from Greek *anthropos*, human being): having a *mollic* horizon and *anthric* properties (2: Ano- and Panto- only).

Somerimollic (sm) (from Spanish *somero*, superficial): having a *mollic* horizon, < 20 cm thick.

Tonguimollic (tm) (from English *tongue*): having a *mollic* horizon that tongues into an underlying layer (2: Ano- and Panto- only; referring to the *mollic* horizon, not to the tongues).

Murshic (mh) (from Polish *mursz*, decay): having a drained *histic* horizon ≥ 20 cm thick, and starting ≤ 10 cm from the soil surface or below a *folic* horizon, with a bulk density[25] of ≥ 0.2 kg dm^{-3} and one or both of the following:
- moderate to strong granular or blocky structure, *or*
- cracks

(*in Histosols only*) (2).

Muusic (mu): (from Sakha *muus*, ice): having ice that is directly overlain by *organic* material (*in Histosols only*) (1: Epi- and Endo- only).

Natric (na) (from Arabic *natroon*, salt): having a *natric* horizon starting ≤ 100 cm from the soil surface (2).

Hypernatric (jn) (from Greek *hyper*, over): having a *natric* horizon with an exchangeable Na percentage (ESP) of ≥ 15 throughout the entire *natric* horizon or within its upper 40 cm, whichever is thinner.

Nudinatric (nn) (from Latin *nudus*, naked): having a *natric* horizon starting at the mineral soil surface.

Nechic (ne) (from Amharic *nech*, white): having uncoated mineral grains of silt or sand size in a darker matrix somewhere within ≤ 5 cm of the mineral soil surface.

Neocambic (nc): *see Cambic.*

Nitic (ni) (from Latin *nitidus*, shiny): having a *nitic* horizon starting ≤ 100 cm from the soil surface. (2)

Novic (nv) (from Latin *novus*, new): having a layer, ≥ 5 cm and < 50 cm thick, overlying a buried soil that is classified with preference according to the 'Rules for classifying soils' (Chapter 2.5).

Areninovic (aj) (from Latin *arena*, sand): having a layer, ≥ 5 cm and < 50 cm thick, with a texture class of sand or loamy sand in its major part, overlying a buried soil that is classified with preference according to the 'Rules for classifying soils' (Chapter 2.5).

Clayinovic (cj) (from English *clay*): having a layer, ≥ 5 cm and < 50 cm thick, with a texture class of clay, sandy clay or silty clay in its major part, overlying a buried soil that is classified with preference according to the 'Rules for classifying soils' (Chapter 2.5).

Loaminovic (lj) (from English *loam*): having a layer, ≥ 5 cm and < 50 cm thick, with a texture class of loam, sandy loam, sandy clay loam, clay loam or silty clay loam in its major part, overlying a buried soil that is classified with preference according to the 'Rules for classifying soils' (Chapter 2.5).

25 For bulk density, the volume is determined after an undried soil sample has been desorbed at 33 kPa (no prior drying), and afterwards the weight is determined oven-dried (see Annex 2).

Siltinovic (sj) (from English *silt*): having a layer, ≥ 5 cm and < 50 cm thick, with a texture class of silt or silt loam in its major part, overlying a buried soil that is classified with preference according to the 'Rules for classifying soils' (Chapter 2.5).

Nudiargic (ng) (from Latin *nudus*, naked, and *argilla*, white clay)**:** having an *argic* horizon starting at the mineral soil surface.

Nudilithic (nt): *see Lithic.*

Nudinatric (nn): *see Natric.*

Ochric (oh): (from Greek *ochros*, pale): having ≥ 0.2 % soil organic carbon (weighted average) in the layer from the mineral soil surface to a depth of 10 cm from the mineral soil surface; and not having a *mollic* or *umbric* horizon and not fulfilling the set of criteria of the Humic qualifier.

Ombric (om) (from Greek *ombros*, rain): having a *histic* horizon saturated predominantly with rainwater (*in Histosols only*).

Ornithic (oc) (from Greek *ornithos*, bird): having a layer ≥ 15 cm thick, with *ornithogenic* material starting ≤ 50 cm from the soil surface (2).

Orthofluvic (of): *see Fluvic*.

Ortsteinic (os) (from German *Ortstein*, locally occurring stone): having a *spodic* horizon that has a subhorizon, ≥ 2.5 cm thick, that is cemented ('ortstein') in ≥ 50% of its horizontal extension (*in Podzols only*).

Oxyaquic (oa) (from Greek *oxys*, sour, and Latin *aqua*, water): having a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface, that is saturated with oxygen-rich water during a period of ≥ 20 consecutive days; and not having *gleyic* or *stagnic* properties in any layer within ≤ 100 cm of the mineral soil surface (2).

Oxygleyic (oy) (from Greek *oxys*, sour, and Russian *gley*, mucky soil mass): not having, within ≤ 100 cm of the mineral soil surface, a layer that meets diagnostic criterion 1 of the *gleyic* properties (*in Gleysols only*).

Pachic (ph) (from Greek *pachys*, thick): having a *mollic* or *umbric* horizon ≥ 50 cm thick.

Pellic (pe) (from Greek *pellos*, dusty): having in the upper 30 cm of the soil a Munsell colour value of ≤ 3 and a chroma of ≤ 2, both moist (*in Vertisols only*).

Petric (pt) (from Greek *petros*, rock): having a cemented or indurated layer starting ≤ 100 cm from the soil surface (refers to a diagnostic horizon of the respective RSG) (1: Epi- and Endo- only).

Nudipetric (np) (from Latin *nudus*, naked): having a cemented or indurated layer starting at the soil surface (refers to a diagnostic horizon of the respective RSG).

Petrocalcic (pc) (from Greek *petros*, rock, and Latin *calx*, lime): having a *petrocalcic* horizon starting ≤ 100 cm from the soil surface (2).

Petroduric (pd) (from Greek *petros*, rock, and Latin *durus*, hard): having a *petroduric* horizon starting ≤ 100 cm from the soil surface (2).

Petrogleyic (py) (from Greek *petros*, rock, and Russian *gley*, mucky soil mass): having a layer ≥ 10 cm thick, within ≤ 100 cm of the mineral soil surface, that meets diagnostic criterion 2 of the *gleyic* properties and of which ≥ 15% (by volume) is cemented (*bog iron*) (2).

Petrogypsic (pg) (from Greek *petros*, rock, and *gypsos*, gypsum): having a *petrogypsic* horizon starting ≤ 100 cm from the soil surface (2).

Petroplinthic (pp) (from Greek *petros*, rock, and *plinthos*, brick): having a *petroplinthic* horizon starting ≤ 100 cm from the soil surface (2).

Petrosalic (ps) (from Greek *petros*, rock, and Latin *sal*, salt): having a layer ≥ 10 cm thick, within ≤ 100 cm of the soil surface, which is cemented by salts more soluble than gypsum (2).

Pisoplinthic (px) (from Latin *pisum*, pea, and Greek *plinthos*, brick): having a *pisoplinthic* horizon starting ≤ 100 cm from the soil surface (2).

Placic (pi) (from Greek *plax*, flat stone): having a layer, between ≥ 0.1 and < 2.5 cm thick, within ≤ 100 cm of the mineral soil surface, that is cemented or indurated by a combination of organic matter, Fe, Mn and/or Al and is continuous to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume) (2: Epi-, Endo- and Amphi- only).

Plaggic (pa) (from Low German *plaggen*, sod): having a *plaggic* horizon (2: Panto- only).

Plinthic (pl) (from Greek *plinthos*, brick): having a *plinthic* horizon starting ≤ 100 cm from the soil surface (2).

Posic (po) (from Latin *positivus*, given): having layer ≥ 30 cm thick, and starting ≤ 100 cm from the soil surface, that has a zero or positive charge (pH_{KCl} - pH_{water} ≥ 0, both in 1:1 solution) (2).

Pretic (pk) (from Portuguese *preto*, black): having a *pretic* horizon (2: Panto- only).

Profondic (pn) (from French *profond*, deep): having an *argic* horizon in which the clay content does not decrease by ≥ 20% (relative) from its maximum within 150 cm of the soil surface.

Protic (pr) (from Greek *protou*, before): showing no soil horizon development, with the exception of a *cryic* horizon, which may be present.

Protoandic (qa): *see Andic.*

Protoargic (qg) (from Greek *protou*, before, and Latin *argilla*, white clay): having an absolute clay increase of ≥ 4% from one layer to the directly underlying layer within ≤ 100 cm of the mineral soil surface (*in Arenosols only*) (1).

Protocalcic (qc): *see Calcic.*

Protospodic (qp): *see Spodic.*

Protovertic (qv): *see Vertic.*

Puffic (pu) (from English *to puff*): having a crust pushed up by salt crystals (*in Solonchaks only*).

Raptic (rp) (from Latin *raptus*, broken): having a *lithic discontinuity* at some depth ≤ 100 cm from the mineral soil surface (1).

Reductaquic (ra) (from Latin *reductus*, drawn back, and *aqua*, water): having a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface, that is saturated with water during the thawing period and that has at some time of the year *reducing conditions* above a *cryic* horizon and within ≤ 100 cm of the mineral soil surface (*in Cryosols only*) (2).

Reductic (rd) (from Latin *reductus*, drawn back): having *reducing conditions* in ≥ 25% of the volume of the fine earth within 100 cm of the soil surface, caused by gaseous emissions, e.g. methane or carbon dioxide, or caused by liquid intrusions other than water, e.g. gasoline (5).

Reductigleyic (ry) (Latin *reductus*, drawn back, and *Russian* gley, mucky soil mass): not having, ≥ 40 cm from the mineral soil surface, a layer that meets diagnostic criterion 2 of the *gleyic* properties (*in Gleysols only*).

Relocatic (rc) (from Latin *re*, again, and *locatus*, put): being in situ remodelled by human activity to a depth of ≥ 100 cm (e.g. by deep ploughing, refilling soil pits or levelling land) and no horizon development after remodelling throughout, at least between 20 cm and 100 cm from the soil surface or between the lower limit of any plough layer, > 20 cm thick, and 100 cm from the soil surface (in *Technosols*, Relocatic is redundant, except in combination with the Ekranic or Linic qualifier); a destroyed diagnostic subsurface horizon may be added with a hyphen, e.g. Spodi-Relocatic, Spodi-Epirelocatic (4: Epi- only).

Rendzic (rz) (from Polish *rzendzic*, to grate in contact with a plough blade): having a *mollic* horizon that contains or directly overlies *calcaric* material containing ≥ 40% calcium carbonate equivalent or that directly overlies calcareous rock containing ≥ 40% calcium carbonate equivalent (2: Ano- and Panto- only).

Somerirendzic (sr) (from Spanish *somero*, superficial): having a *mollic* horizon, < 20 cm thick, that directly overlies calcareous rock containing ≥ 40% calcium carbonate equivalent.

Retic (rt) (from Latin *rete*, net): having *retic* properties starting ≤ 100 cm from the soil surface, but not having *albeluvic glossae*.

Rheic (rh) (from Greek *rhen*, to flow): having a *histic* horizon saturated predominantly with groundwater or flowing water (*in Histosols only*).

Rhodic (ro): (from Greek *rhodon*, rose): having between 25 and 150 cm of the soil surface, a layer ≥ 30 cm thick, that has, in ≥ 90% of its exposed area, a Munsell colour hue redder than 5YR moist, a value of < 4 moist, and a value dry, no more than one unit higher than the moist value (2: except Epi-).

Rockic (rk): (from English *rock*): having *continuous rock* or *technic hard* material that is directly overlain by *organic* material (*in Histosols only*) (1: Epi- and Endo-only).

Rubic (ru): (from Latin *ruber*, red): having between 25 and 100 cm of the soil surface, a layer ≥ 30 cm thick, that does not consist of *albic* material and that has, in ≥ 90% of its exposed area, a Munsell colour hue redder than 10YR and/or a chroma of ≥ 5, both moist (in Arenosols only) (2: except Epi-).

Rustic (rs) (from English *rust*): having a *spodic* horizon in which the ratio of the percentage of Fe_{ox} to the percentage of *soil organic carbon* is ≥ 6 throughout (*in Podzols only*).

Salic (sz) (from Latin *sal*, salt): having a *salic* horizon starting ≤ 100 cm from the soil surface (2).

- **Hypersalic (jz)** (from Greek *hyper*, over): having within ≤ 100 cm of the soil surface a layer that has an EC_e of ≥ 30 dS m^{-1} at 25 °C (2).
- **Protosalic (qz)** (from Greek *protou*, before): having within ≤ 100 cm of the soil surface a layer that has an EC_e of ≥ 4 dS m^{-1} at 25 °C; and not having a *salic* horizon starting ≤ 100 cm from the soil surface (2).

Sapric (sa) (from Greek *sapros*, rotted): having, after rubbing, less than one-sixth (by volume) of the *organic* material consisting of recognizable plant tissue within 100 cm of the soil surface (*in Histosols only*).

Sideralic (se) (from Greek *sideros*, iron, and *Latin* alumen, alum): having within ≤ 100 cm of the soil surface a layer that has *sideralic* properties (2).

- **Hypersideralic (jr)** (from Greek *hyper*, over): having within ≤ 100 cm of the soil surface a layer that has *sideralic* properties and a CEC (by 1 *M* NH_4OAc, pH 7) of < 16 $cmol_c$ kg^{-1} clay (2).

Silandic (sn) (from Latin *silicia*, silicon-containing material, and Japanese *an*, dark, and *do*, soil): having within ≤ 100 cm of the soil surface one or more layers with a combined thickness of ≥ 15 cm with *andic* properties and a Si_{ox} content of ≥ 0.6% or an Al_{py}/Al_{ox} of < 0.5 (*in Andosols only*) (2).

Siltic (sl) (from English *silt*): having a texture class of silt or silt loam in a layer ≥ 30 cm thick, within ≤ 100 cm of the mineral soil surface or in the major part between the mineral soil surface and *continuous rock, technic hard* material or a cemented or indurated layer starting < 60 cm from the mineral soil surface (2; no subqualifier if *continuous rock* or *technic hard* material starts < 60 cm from the mineral soil surface).

Skeletic (sk) (from Greek *skeletos*, dried out): having ≥ 40% (by volume) coarse fragments averaged over a depth of 100 cm from the soil surface or to *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower (5).

Akroskeletic (kk) (from Greek *akra*, top): having ≥ 40% of the soil surface covered by fragments that have a greatest dimension ≥ 6 cm (stones, boulders or large boulders).

Orthoskeletic (ok) (from Greek *orthos*, right): having:

- ≥ 40% of the soil surface covered by fragments that have a greatest dimension ≥ 6 cm (stones, boulders or large boulders), *and*
- ≥ 40% (by volume) coarse fragments averaged over a depth of 100 cm from the soil surface or to *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower (5).

Technoskeletic (tk) (from Greek *technae*, art): having ≥ 40% (by volume) coarse fragments, that meet the criteria of *artefacts*, averaged over a depth of 100 cm from the soil surface or to *continuous rock, technic hard* material or a cemented or indurated layer, whichever is shallower (5).

Sodic (so) (from Spanish *soda*, gaseous water): having a layer ≥ 20 cm thick, and starting ≤ 100 cm from the soil surface, that has ≥ 15% Na plus Mg and ≥ 6% Na on the exchange complex; and not having a *natric* horizon starting ≤ 100 cm from the soil surface (2).

Argisodic (as) (from Latin *argilla*, white clay): having an *argic* horizon, starting ≤ 100 cm from the soil surface, that has ≥ 15% Na plus Mg and ≥ 6% Na on the exchange complex throughout the *argic* horizon or within its upper 40 cm, whichever is thinner (2).

Protosodic (qs) (from Greek *protou*, before): having a layer ≥ 20 cm thick, and starting ≤ 100 cm from the soil surface, that has ≥ 6% Na on the exchange complex; and not having a *natric* horizon starting ≤ 100 cm from the soil surface (2).

Sombric (sb) (from French *sombre*, shade): having a *sombric* horizon starting ≤ 150 cm from the soil surface (2).

Someric (si) (from Spanish *somero*, superficial): having a *mollic* or *umbric* horizon, < 20 cm thick.

Spodic (sd) (from Greek *spodos*, wood ash): having a *spodic* horizon starting ≤ 200 cm from the mineral soil surface (2).

Hyperspodic (jp) (from Greek *hyper*, over): having a *spodic* horizon ≥ 100 cm thick.

Protospodic (qp) (from Greek *protou*, before): having a layer ≥ 2.5 cm thick, and starting ≤ 100 cm from the mineral soil surface, that has:

- ≥ 0.5% *soil organic carbon* in its uppermost 1 cm, *and*
- a sublayer with an Al_{ox} + ½Fe_{ox} value of ≥ 0.5% that is ≥ 2 times higher than the lowest Al_{ox} + ½Fe_{ox} value of all overlying mineral layers; *and*

not having a *spodic* horizon starting ≤ 200 cm from the mineral soil surface (2).

Spolic (sp) (from Latin *spoliare*, to exploit): having a layer ≥ 20 cm thick, within ≤ 100 cm of the soil surface, with ≥ 20% (by volume, weighted average) *artefacts* containing ≥ 35% (by volume) industrial waste (mine spoil, dredgings, slag, ash, rubble, etc.) (*in Technosols only*) (2).

Stagnic (st) (from Latin *stagnare*, to stagnate): having a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface, that does not form part of a *hydragric* horizon and that has:
- *stagnic* properties in which the area of reductimorphic colours plus the area of oximorphic colours is ≥ 25% of the layer's total area, *and*
- *reducing conditions* for some time during the year in the major part of the layer's volume that has the reductimorphic colours (2).

Protostagnic (qw) (from Greek *protou*, before): having a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface, that does not form part of a *hydragric* horizon and that has:
- *stagnic* properties in which the area of reductimorphic colours plus the area of oximorphic colours is ≥ 10% and < 25% of the layer's total area, *and*
- *reducing conditions* for some time during the year in the major part of the layer's volume that has the reductimorphic colours (2).

Relictistagnic (rw) (from Latin *relictus*, left back): having a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface, that has:
- *stagnic* properties in which the area of reductimorphic colours plus the area of oximorphic colours is ≥ 25% of the layer's total area, *and*
- no *reducing conditions* (2).

Subaquatic (sq) (from Latin *sub*, under, and *aqua*, water): being permanently submerged by water not deeper than 200 cm.

Sulfatic (su) (from Latin *sulpur*, sulfur): having a *salic* horizon with a soil solution (1:1 in water) with $[SO_4^{2-}] > 2*[HCO_3^-] > 2*[Cl^-]$ (*in Solonchaks only*).

Sulfidic (sf) (from Latin *sulpur*, sulfur): having *sulfidic* material ≥ 15 cm thick, and starting ≤ 100 cm from the soil surface (2).

Hypersulfidic (js) (from Greek *hyper*, over): having *hypersulfidic* material ≥ 15 cm thick, and starting ≤ 100 cm from the soil surface (2).

Hyposulfidic (ws) (from Greek *hypo*, under): having *hyposulfidic* material ≥ 15 cm thick, and starting ≤ 100 cm from the soil surface (2).

Takyric (ty) (from Turkic languages *takyr*, barren land): having *takyric* properties.

Technic (te) (from Greek *technae*, art): having ≥ 10% (by volume, weighted average) *artefacts* in the upper 100 cm from the soil surface or to *continuous rock* or a cemented or indurated layer, whichever is shallower; or having a layer ≥ 10 cm thick, and starting ≤ 90 cm from the soil surface, with ≥ 50% (by volume, weighted average) *artefacts* (5 or 2: Epi- and Endo- only).

Hypertechnic (jt) (from Greek *hyper*, over): having ≥ 20% (by volume, weighted average) *artefacts* in the upper 100 cm from the soil surface or to *continuous rock* or a cemented or indurated layer, whichever is shallower (5).

Prototechnic (qt) (from Greek *protou*, before): having ≥ 5% (by volume, weighted average) *artefacts* in the upper 100 cm from the soil surface or to *continuous rock* or a cemented or indurated layer, whichever is shallower; or having a layer ≥ 10 cm thick, and starting ≤ 90 cm from the soil surface, with ≥ 25% (by volume, weighted average) *artefacts* (5 or 2: Epi- and Endo- only).

Technoleptic (tl): *see Technic.*

Tephric (tf) (from Greek *tephra*, pile ash): having *tephric* material, starting ≤ 50 cm from the soil surface, that is
- ≥ 30 cm thick, *or*
- ≥ 10 cm thick and directly overlying c*ontinuous rock*, *technic hard* material or a cemented or indurated layer (2).

Prototephric (qf) (from Greek *protou*, before): having a layer with *tephric* material ≥ 10 and < 30 cm thick, and starting ≤ 50 cm from the soil surface and not reaching *continuous rock*, *technic hard* material or a cemented or indurated layer.

Terric (tr) (from Latin *terra*, earth): having a *terric* horizon, *and*
- in Anthrosols, not having a *hortic*, *irragric*, *plaggic* or *pretic* horizon with a thickness of ≥ 50 cm (2: Panto- only), *and*
- in other soils, not having a *hortic*, *irragric*, *plaggic* or *pretic* horizon.

Thionic (ti) (from Greek *theion*, sulfur): having a *thionic* horizon starting ≤ 100 cm from the soil surface (2).

Hyperthionic (ji) (from Greek *hyper*, over): having a *thionic* horizon starting ≤ 100 cm from the soil surface and having a pH (1:1 in water) < 3.5 (2).

Hypothionic (wi) (from Greek *hypo*, under): having a *thionic* horizon starting ≤ 100 cm from the soil surface and having a pH (1:1 in water) between ≥ 3.5 and < 4 (2).

Thixotropic (tp) (from Greek *thixis*, contact, and Greek *tropae*, reversion): having in some layer within ≤ 50 cm of the soil surface, material that changes, under pressure or by rubbing, from a plastic solid into a liquefied stage and back into the solid condition.

Tidalic (td) (from English *tide*): affected by tidal water, i.e. located between the line of mean high water springs and the line of mean low water springs.

Tonguic (to) (from English *tongue*): showing tonguing of a *chernic*, *mollic* or *umbric* horizon into an underlying layer.

Toxic (tx) (from Greek *toxikon*, arrow poison): having in some layer within ≤ 50 cm of the soil surface, toxic concentrations of organic or inorganic substances other than ions of Al, Fe, Na, Ca and Mg, or having radioactivity dangerous to humans.

Anthrotoxic (at) (from Greek *anthropos*, human being): having in some layer within ≤ 50 cm of the soil surface, sufficiently high and persistent concentrations of organic or inorganic substances to markedly affect the health of humans who come in regular contact with the soil.

Phytotoxic (yx) (from Greek *phyton*, plant): having in some layer within ≤ 50 cm of the soil surface, sufficiently high concentrations of ions other than Al, Fe, Na, Ca and Mg, to markedly affect plant growth.

Radiotoxic (rx) (from Latin *radius*, ray): having radioactivity, dangerous to humans.

Zootoxic (zx) (from Greek *zoae*, life): having in some layer within ≤ 50 cm of the soil surface, sufficiently high and persistent concentrations of organic or inorganic substances to markedly affect the health of animals, including humans, that ingest plants grown on these soils.

Transportic (tn) (from Latin *transportare*, to transport): having at the soil surface a layer ≥ 20 cm thick, or with a thickness of ≥ 50% of the entire soil if *continuous rock*, *technic hard* material or a cemented or indurated layer is starting ≤ 40 cm from the soil surface, with soil material that does not meet the criteria of *artefacts*; and that has been moved from a source area outside the immediate vicinity of the soil by intentional human activity, usually with the aid of machinery, and without substantial reworking or displacement by natural forces (2: Ano- and Panto- only; no subqualifier if *continuous rock* or *technic hard* material starts ≤ 40 cm from the mineral soil surface).

Organotransportic (ot) (from Greek *organon*, tool): having at the soil surface a layer ≥ 20 cm thick, or with a thickness of ≥ 50% of the entire soil if *continuous rock*, *technic hard* material or a cemented or indurated layer is starting ≤ 40 cm from the soil surface, with *organic* material that does not meet the criteria of *artefacts;* and that has been moved from a source area outside the immediate vicinity of the soil by intentional human activity, usually with the aid of machinery, and without substantial reworking or displacement by natural forces (2: Ano- and Panto- only; no subqualifier if *continuous rock* or *technic hard* material starts ≤ 40 cm from the mineral soil surface).

Turbic (tu) (from Latin *turbare*, to disturb): having cryoturbation features (mixed material, disrupted soil horizons, involutions, organic intrusions, frost heave, separation of coarse from fine materials, cracks or patterned ground) within 100 cm of the soil surface, above a *cryic* horizon or above a seasonally frozen layer (2: only if clearly recognizable as layer).

Relictiturbic (rb) (from Latin *relictus*, left back): having cryoturbation features within 100 cm of the soil surface, caused by frost action in the past (2: only if clearly recognizable as layer).

Umbric (um) (from Latin *umbra*, shade): having an *umbric* horizon (2: Ano- and Panto- only).

Anthroumbric (aw) (from Greek *anthropos*, human being): having an *umbric* horizon and *anthric* properties (2: Ano- and Panto- only).

Someriumbric (sw) (from Spanish *somero*, superficial): having an *umbric* horizon, < 20 cm thick.

Tonguiumbric (tw) (from English *tongue*): having an *umbric* horizon that tongues into an underlying layer (2: Ano- and Panto- only; referring to the *umbric* horizon, not to the tongues).

Urbic (ub) (from Latin *urbs*, city): having a layer ≥ 20 cm thick, within ≤ 100 cm of the soil surface, with ≥ 20% (by volume, weighted average) *artefacts* containing ≥ 35% (by volume) rubble and refuse of human settlements (*in Technosols only*) (2).

Uterquic (uq) (from Latin *uterque*, both): having a layer with dominant *gleyic* properties and some parts with *stagnic* properties.

Vermic (vm) (from Latin *vermis*, worm): having ≥ 50% (by volume, weighted average) of worm holes, casts, or filled animal burrows in the upper 100 cm of the soil or to *continuous rock*, *technic hard* material or a cemented or indurated layer, whichever is shallower.

Vertic (vr) (from Latin *vertere*, to turn): having a *vertic* horizon starting ≤ 100 cm from the soil surface (2).

Protovertic (qv) (from Greek *protou*, before): having a *protovertic* horizon starting ≤ 100 cm from the soil surfaced; and not having a *vertic* horizon starting ≤ 100 cm from the soil surface (2).

Vetic (vt): (from Latin *vetus*, old): having between 25 and 100 cm of the soil surface a layer that has a sum of exchangeable bases (by 1 *M* NH_4OAc, pH 7) plus exchangeable Al (by 1 *M* KCl, unbuffered) of < 6 $cmol_c$ kg^{-1} clay (2).

Vitric (vi) (from Latin *vitrum*, glass): having within ≤ 100 cm of the soil surface, one or more layers with *andic* or *vitric* properties with a combined thickness of ≥ 30 cm (in *Cambisols* ≥ 15 cm), of which ≥ 15 cm (in *Cambisols* ≥ 7.5 cm) have *vitric* properties (2).

Xanthic (xa) (from Greek *xanthos*, yellow): having a *ferralic* horizon that has in a subhorizon ≥ 30 cm thick, and starting ≤ 75 cm of the upper limit of the *ferralic* horizon, in ≥ 90% of its exposed area, a Munsell colour hue of 7.5YR or yellower, a value of ≥ 4 and a chroma of ≥ 5, all moist.

Yermic (ye) (from Spanish *yermo*, desert): having *yermic* properties, including a desert pavement.

Nudiyermic (ny) (from Latin *nudus*, naked): having *yermic* properties without a desert pavement.

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Annex 1

Description, distribution, use and management of Reference Soil Groups

This annex gives an overview of all the RSGs (in alphabetical order). A brief description is provided with corresponding names in other major soil classification systems, followed by the regional distribution of each group. Land use and management concludes each description. More detailed information on each RSG, including morphological, chemical and physical characteristics and genesis, is available in FAO (2001a) and a number of CD-ROMs (FAO, 2001b, 2003 and 2005). All these publications reflect the first edition of the WRB (FAO, 1998); new publications based on the current (third) edition are planned for the future.

ACRISOLS

Acrisols have a higher clay content in the subsoil than in the topsoil, as a result of pedogenetic processes (especially clay migration) leading to an *argic* subsoil horizon. Acrisols have low-activity clays in the *argic* horizon and a low base saturation in the 50–100 cm depth. Many Acrisols correlate with *Red yellow podzolic soils* (e.g. Indonesia), *Argissolos* (Brazil), *Kurosols* (Australia), *Sols ferralitiques fortement ou moyennement désaturés* (France) and *Ultisols* with low-activity clays (United States of America).

Summary description of Acrisols

Connotation: From Latin *acer*, very acid. Strongly weathered acid soils with low base saturation at some depth.

Parent material: On a wide variety of parent materials, especially from the weathering of acid rocks; and notably in strongly weathered clays that are undergoing further degradation.

Environment: Mostly old land surfaces with hilly or undulating topography, in regions with a wet tropical/monsoonal, subtropical or warm temperate climate. Forest is the natural vegetation type. In South America, Acrisols are also found under savannah.

Profile development: Pedogenetic differentiation of clay content, with a lower content in the topsoil and a higher content in the subsoil; leaching of base cations owing to the humid environment and advanced degree of weathering. The loss of iron oxides together with clay minerals may lead to a bleached eluviation horizon between the surface horizon and the *argic* subsurface horizon but Acrisols lack the *retic* properties of the Retisols.

Regional distribution of Acrisols

Acrisols are found in humid tropical, humid subtropical and warm temperate regions and are most extensive in Southeast Asia, the southern fringes of the Amazon Basin, the southeast of the United States of America and in both East and West Africa. There are about 1 000 million ha of Acrisols worldwide.

Management and use of Acrisols

Preservation of the surface soil with its all-important organic matter and preventing erosion are preconditions for farming on Acrisols. Mechanical clearing of natural forest by extraction of root balls and filling of the holes with surrounding surface soil produces land that is largely sterile where Al concentrations of the former subsoil reach toxic levels.

Adapted cropping systems with complete fertilization and careful management are required if sedentary farming is to be practised on Acrisols. The widely used slash-and-burn agriculture (shifting cultivation) may seem primitive but it is a well-adapted form of land use, developed over centuries of trial and error. If occupation periods are short (one or a few years only) and followed by a sufficiently long regeneration period (up to several decades), this system makes good use of the limited resources of Acrisols. Agroforestry is recommended as a soil-protecting alternative to shifting cultivation to achieve higher yields without requiring expensive inputs.

Low-input farming on Acrisols is not very rewarding. Undemanding acid-tolerant cash crops such as pineapple, cashew, tea and rubber can be grown with some success. Increasing areas of Acrisols are planted with oil-palm (e.g. in Malaysia and on Sumatra). Large areas of Acrisols are under forest, ranging from high, dense rain forest to open woodland. Most of the tree roots are concentrated in the humus surface horizon with only a few tap-roots extending down into the subsoil. Acrisols are suitable for production of rainfed and irrigated crops only after liming and full fertilization. Rotation of annual crops with improved pasture maintains the organic matter content.

ALISOLS

Alisols have a higher clay content in the subsoil than in the topsoil, as a result of pedogenetic processes (especially clay migration) leading to an *argic* subsoil horizon. Alisols have high-activity clays throughout the *argic* horizon and a low base saturation in the 50–100 cm depth. They occur predominantly in humid tropical, humid subtropical and humid temperate regions. Many Alisols correlate with *Parabraunerden* (Germany), *Argissolos* (Brazil), *Ultisols* with high-activity clays (United States of America), *Kurosols* (Australia), and *Fersialsols* and *Sols fersiallitiques très lessivés* (France).

Summary description of Alisols

Connotation: Soils with a low base saturation at some depth; from Latin *alumen*, alum.

Parent material: A wide variety of parent materials. Most occurrences of Alisols reported so far are on weathering products of basic rocks and unconsolidated materials.

Environment: Most common in hilly or undulating topography, in humid tropical, humid subtropical and monsoon climates and in humid temperate climates.

Profile development: Pedogenetic differentiation of clay content, with a lower content in the topsoil and a higher content in the subsoil, leaching of base cations owing to the humid environment without advanced weathering of high-activity clays. The loss of iron oxides together with clay minerals may lead to a bleached eluviation horizon between the surface horizon and the *argic* subsurface horizon but Alisols lack the *retic* properties of the Retisols.

Regional distribution of Alisols

Major occurrences of Alisols are in Latin America (Ecuador, Nicaragua, Venezuela, Colombia, Peru and Brazil), in the West Indies (Jamaica, Martinique and Saint Lucia), in West Africa, the highlands of East Africa, Madagascar and in Southeast Asia and northern Australia. FAO (2001a) estimates that about 100 million ha of these soils are used for agriculture in the tropics.

Alisols occur also in subtropical regions; they are found in China, Japan and the southeast of the United States of America and minor occurrences have been reported from around the Mediterranean Sea (Italy, France and Greece). They also occur in humid temperate regions.

Management and use of Alisols

Alisols occur predominantly on hilly or undulating topography. The generally unstable surface soil of cultivated Alisols makes them susceptible to erosion; truncated soils are quite common. Toxic levels of Al at shallow depth and poor natural soil fertility are further constraints in many Alisols. As a consequence, many Alisols allow only cultivation of shallow-rooting crops and crops suffer from drought stress in the dry season. A significant proportion of Alisols are unproductive for a wide variety of crops. The use of acid-tolerant crops or low-volume grazing is common. The productivity of Alisols in subsistence agriculture is generally low. Where fully limed and fertilized, crops on Alisols may benefit from the considerable CEC and good water-holding capacity, and Alisols may eventually grade into Luvisols. Alisols are increasingly planted with Al-tolerant estate crops such as tea and rubber but also to oil-palm, and in places, to coffee, cashew and sugar cane.

ANDOSOLS

Andosols accommodate soils that develop in glass-rich volcanic ejecta under almost any climate (except under hyperarid climate conditions). However, Andosols may also develop in other silicate-rich materials under acid weathering in humid and perhumid climates. Many Andosols belong to *Kuroboku* (Japan), *Andisols* (United States of America), *Andosols* and *Vitrisols* (France), and *Volcanic ash soils* (Russia).

Summary description of Andosols

Connotation: Typically dark soils of volcanic landscapes; from Japanese *an*, dark, and *do*, soil.

Parent material: Glass-rich volcanic ejecta (mainly ash, but also tuff, pumice, cinders and others) under almost any climate or other silicate-rich material under acid weathering in humid and perhumid climates.

Environment: Undulating to mountainous, arctic to tropical, mostly humid regions with a wide range of vegetation types.

Profile development: Rapid weathering of volcanic glasses results in accumulation of stable organomineral complexes (Aluandic qualifier) or short-range-order minerals such as allophane and imogolite (Silandic qualifier). Additionally, ferrihydrite is formed. Acid weathering of other silicate-rich material in humid and perhumid climates also leads to the formation of stable organo-mineral complexes.

Regional distribution of Andosols

Andosols occur in volcanic regions all over the world. Important concentrations are found around the Pacific rim ('Pacific ring of fire'): on the west coast of South America, in Central America, Mexico, the United States of America (the Rocky Mountains, Alaska), Kamchatka, Japan, the Philippine Archipelago, Indonesia, Papua New Guinea and New Zealand. They are also prominent on many islands in the Pacific: Fiji, Vanuatu, New Caledonia, Samoa and Hawaii. In Africa, major occurrences of Andosols are found along the East African Rift Valley in Kenya, Rwanda and Ethiopia, but also in Cameroon and in Madagascar. In Europe, Andosols occur in Italy, France, Germany and Iceland. The total area with Andosols is estimated at some 110 million ha or less than 1 percent of the global land surface. More than half of this area is situated in the tropics. Andosols originating from parent materials other than glass-rich volcanic ejecta occur in humid (often mountainous) regions, e.g. in Rio Grande do Sul, Southeast Brazil.

Management and use of Andosols

Andosols have a high potential for agricultural production, but many of them are not used to their potential. Andosols are generally fertile soils, particularly Andosols in intermediate or basic volcanic ash and not exposed to excessive leaching. The strong phosphate fixation of Andosols (caused by active Al and Fe) is a problem. Ameliorative measures to reduce this effect include application of lime, silica, organic matter and phosphate fertilizer.

Andosols have favourable properties for cultivation, plant roots and water storage. Strongly hydrated Andosols are difficult to till because of their low bearing capacity and their stickiness.

Andosols are planted with a wide variety of crops including sugar cane, tobacco, sweet potato (tolerant of low phosphate levels), tea, vegetables, wheat and orchard crops. Andosols on steep slopes are perhaps best kept under forest. Paddy rice cultivation is a major land use on Andosols in lowlands with shallow groundwater.

ANTHROSOLS

Anthrosols comprise soils that have been modified profoundly through human activities, such as addition of *organic* or *mineral* material, charcoal or household wastes, or irrigation and cultivation. The group includes soils otherwise known as *Plaggen soils*, *Paddy soils*, *Oasis soils*, or *Terra Preta de Indio*. Many of them correspond to *Highly cultivated soils* and *Anciently irrigated soils* (Russia), *Terrestrische anthropogene Böden* (Germany), *Anthroposols* (Australia) and *Anthrosols* (China).

Summary description of Anthrosols

Connotation: Soils with prominent characteristics that result from human activities; from Greek *anthropos*, human being.

Parent material: Virtually any soil material, modified by long-continued cultivation or addition of material.

Environment: In many regions where people have been practising agriculture for a long time.

Profile development: Influence of humans is normally restricted to the surface horizons; the horizon differentiation of a buried soil may still be intact at some depth.

Regional distribution of Anthrosols

Anthrosols are found wherever people have practised agriculture for a long time. Anthrosols with *plaggic* horizons are most common in northwestern central Europe. Together with Anthrosols with a *terric* horizon, they cover more than 500 000 ha.

Anthrosols with *irragric* horizons are found in irrigation areas in dry regions, e.g. in Mesopotamia, in oases in desert regions of Central Asia and in parts of India. Anthrosols with an *anthraquic* horizon overlying a *hydragric* horizon (*paddy soils*) occupy vast areas in China and in parts of South and Southeast Asia (e.g. Sri Lanka, Viet Nam, Thailand and Indonesia). Anthrosols with hortic horizons are found all over the world where humans have fertilized the soil with household wastes and manure. The *Terra Preta de Indio* in the Amazon Region commonly has a *pretic* horizon.

Management and use of Anthrosols

Plaggic horizons have favourable physical properties (porosity, root penetration and moisture availability), but many also have less satisfactory chemical characteristics (acidity and nutrient deficiencies). Rye, oats, barley, potato and also the more demanding sugar beet and summer wheat are common crops on European Anthrosols with a *plaggic* horizon. Prior to the advent of chemical fertilizers, rye yields were 700–1 100 kg/ha, or 4–5 times the quantity of seed used. Today, these soils receive generous doses of fertilizers and average per-hectare yield levels for rye, barley and summer wheat are 5 000, 4 500 and 5 500 kg, respectively. Sugar beet and potato produce 40–50 tonnes/ha. Nowadays, they are increasingly used for production of silage maize and grass; per-hectare production levels of 12–13 tonnes of dry maize silage and 1013 tonnes of dry grass are considered normal. In places, Anthrosols with *plaggic* horizons are used for tree nurseries and horticulture. The good drainage and the dark colour of the surface soil (early warming in spring) make it possible to till and sow or plant early in the season. Soils with deep *plaggic* horizons in the Netherlands were in demand for the cultivation of tobacco until the 1950s.

Many garden soils, e.g. in Europe and China, have a *hortic* horizon. They have been enriched with organic manure. Kitchen soils are another group of Anthrosols with a *hortic* horizon. Well-known examples are situated on river terraces in southern Maryland, United States of America. They have deep, black topsoils formed in layers of kitchen refuse (mainly oyster shells, fish bones, etc.) from early Indian habitations. Many countries possess small areas of soils that were modified by early inhabitants. All *hortic* horizons provide a good habitat for soil fauna.

Wet cultivation of rice leads to the development of an *anthraquic* horizon and after long time of management also to an underlying *hydragric* horizon. Puddling of wetland rice fields (involving destruction of the natural soil structure by intensive tillage when the soil is saturated with water) is done intentionally, *inter alia* to reduce percolation losses.

Anthrosols with *irragric* horizons are formed as a result of prolonged sedimentation (predominantly silt and clay) from irrigation water, and their thickness may reach 100 cm. A special case is found in depression areas where dryland crops are commonly planted on constructed ridges that alternate with drainage furrows. The original soil profile of the ridge areas is buried under a thick layer of added soil material.

In parts of Western Europe, notably in Ireland and the United Kingdom, calcareous materials (e.g. beach sands) were carted to areas with acid Arenosols, Podzols, Retisols and Histosols. Eventually these modified surface layers of mineral material turned into *terric* horizons that gave the soil much improved properties for arable cropping compared to the original surface soil. Recently, *terric* horizons are created by single additions of mineral material that is thoroughly mixed into the original soil, e.g. in southern Italy. In Central Mexico, deep soils were constructed of organic-matter-rich lacustrine sediments, thus forming a system of artificial islands and channels (*chinampas*). These soils have a terric horizon and were the most productive lands of the Aztec empire; now most of these soils are affected by salinization.

Typical for Amazonian Dark Earths (*Terra Preta de Indio*) is the *pretic* horizon which has been created by adding charcoal, plant residues and kitchen refuse.

ARENOSOLS

Arenosols comprise deep sandy soils. This includes soils in residual sands after *in situ* weathering of usually quartz-rich sediments or rock, and soils in recently deposited sands such as dunes in deserts and beach lands. Corresponding soils in other classification systems include *Psamments* (United States of America), *Sols minéraux bruts* and *Sols peu évolués* (France), *Arenic Rudosols/Tenosols* (Australia), *Psammozems* (Russia) and *Neossolos* (Brazil).

Summary description of Arenosols

Connotation: Sandy soils; from Latin *arena*, sand.

Parent material: Unconsolidated, in places calcareous, translocated materials of sandy texture; relatively small areas of Arenosols occur in extremely weathered siliceous rock.

Environment: From arid to humid and perhumid, and from extremely cold to extremely hot; landforms vary from recent dunes, beach ridges and sandy plains to very old plateaus; the vegetation ranges from desert over scattered vegetation (mostly grassy) to light forest.

Profile development: In the dry zone, there is little or no soil development. Arenosols in the perhumid tropics tend to develop thick eluviation horizons composed of *albic* material (where a *spodic* horizon may occur below 200 cm from the soil surface) or tend to evolve from Ferralsols after kaolinite weathering.

Regional distribution of Arenosols

Arenosols are one of the most extensive RSGs in the world; including shifting sands and active dunes, they cover about 1 300 million ha or 10 percent of the land surface. Vast expanses of deep aeolian sands are found on the Central African plateau between the equator and 30 °S. These Kalahari Sands form the largest body of sands on earth. Other areas of Arenosols occur in the Sahelian region of Africa, various parts of the Sahara, central and western Australia, the Near East and western China. Sandy coastal plains and coastal dune areas are of smaller geographic extent.

Although Arenosols occupy large parts of arid and semi-arid regions, they are found in the widest possible range of climates, from very arid to very humid and from cold to hot. Arenosols are widespread in aeolian landscapes but occur also in marine, littoral and lacustrine sands and in coarse-grained weathering mantles of siliceous rocks, mainly sandstone, quartzite and granite. There is no limitation as to age or period in which soil formation took place. Arenosols occur on very old surfaces as well as in very recent landforms, and may be associated with almost any type of vegetation.

Management and use of Arenosols

Arenosols occur in widely differing environments, and possibilities to use them for agriculture vary accordingly. The characteristic that all Arenosols have in common is their coarse texture, accounting for their generally high permeability and low water and nutrient storage capacity. On the other hand, Arenosols offer ease of cultivation, rooting and harvesting of root and tuber crops.

Arenosols in **arid and semi-arid lands** with annual rainfall of less than 300 mm are predominantly used for extensive (nomadic) grazing. Dry farming is possible where the annual rainfall exceeds 300 mm. Low coherence, low nutrient storage capacity and high sensitivity to erosion are serious limitations of Arenosols in the dry zone. Good yields of small grains, melons, pulses and fodder crops have been realized on irrigated Arenosols, but high percolation losses may make surface irrigation impracticable. Drip or trickle irrigation, possibly combined with careful dosage of fertilizers, may remedy the situation. Many areas with Arenosols in the Sahelian zone (annual rainfall of 300–600 mm) are transitional to the Sahara and their soils are covered with sparse vegetation. Uncontrolled grazing and clearing for cultivation without appropriate soil conservation measures can easily destabilize these soils, reverting them back to shifting dunes.

Arenosols in the **humid and subhumid temperate zone** have limitations similar to those of the dry zone, albeit that drought is a less serious constraint. In some instances, e.g. in horticulture, the low water storage of Arenosols is considered advantageous because the soils warm up early in the season. In mixed farming systems (which are much more common) with cereals, fodder crops and grassland, supplementary sprinkler irrigation is applied during dry spells. A large part of the Arenosols of the temperate zone is under forest, either production forest or natural stands in carefully managed nature reserves.

Arenosols in the **humid tropics** are best left under their natural vegetation, particularly the deeply weathered Arenosols consisting of *albic* material. As nutrient elements are all concentrated in the biomass and in the soil organic matter, clearing of the land will inevitably produce infertile badlands without ecological or economic value. Under forest, the land can still produce some timber (e.g. *Agathis spp.*) and wood for the pulp and paper industry. Permanent cultivation of annual crops would require management inputs that are usually not economically justifiable. In places, Arenosols have been planted with perennial crops such as rubber and pepper; coastal sands are widely planted with estate crops such as coconut, cashew, Casuarinas and pine, especially where good quality groundwater is within reach of the root system. Root and tuber crops benefit from the ease of harvesting, notably cassava with its tolerance of low nutrient levels. Groundnut (including Bambara nut) can be found on the better soils.

Arenosols and related soils with a sandy surface texture in some regions (e.g. Western Australia and parts of South Africa) may be prone to develop water-repellency, typically caused by hydrophobic exudates of soil fungi that coat sand grains. Water-repellency is most intense after lengthy spells of hot, dry weather and leads to differential water infiltration. This is thought to have ecological significance in promoting plant species diversity (e.g. in Namaqualand). Wetting agents (surfactants such as calcium lignosulfonate) are sometimes used to achieve more uniform water penetration under irrigation. Dryland wheat farmers in Australia mine clay and apply it to their sandy soils with specialized machinery. The results (more uniform germination and better herbicide efficiency) can be economically attractive where a local source of clay is available.

CALCISOLS

Calcisols accommodate soils with substantial accumulation of secondary carbonates. Calcisols are widespread in arid and semi-arid environments, often associated with highly calcareous parent materials. Many Calcisols have formerly been called *Desert soils*. In the United States of America most of them belong to the *Calcids,* and in Australia to the *Calcarosols*. In the Soil Map of the World (FAO–UNESCO, 1971–1981) most of them belong to the *Xerosols* and to a lesser extent to the *Yermosols*.

Summary description of Calcisols

Connotation: Soils with substantial accumulation of secondary lime; from Latin *calx*, lime.

Parent material: Mostly alluvial, colluvial and aeolian deposits of base-rich weathering material.

Environment: Level to hilly land in arid and semi-arid regions. The natural vegetation is sparse and dominated by xerophytic shrubs and trees and/or ephemeral grasses and herbs.

Profile development: Typical Calcisols have a pale brown surface horizon; substantial accumulation of secondary carbonates occurs within 100 cm of the soil surface.

Regional distribution of Calcisols

It is difficult to quantify the worldwide extent of Calcisols with any measure of accuracy. Many Calcisols occur together with Solonchaks that are actually salt-affected Calcisols, and/or with other soils having accumulations of secondary carbonates not sufficient to key out as Calcisols. The total Calcisol area may well amount to some 1 000 million ha, most of them in the arid and semi-arid tropics and subtropics of both hemispheres.

Management and use of Calcisols

Vast areas of so-called natural Calcisols are under shrubs, grasses and herbs and are used for extensive grazing. Drought-tolerant crops such as sunflower might be grown rainfed, preferably after one or a few fallow years, but Calcisols reach their full productive capacity only when irrigated carefully. Extensive areas of Calcisols are used for production of irrigated winter wheat, melons and cotton in the Mediterranean zone. *Sorghum bicolor* ('el sabeem') and fodder crops, such as Rhodes grass and alfalfa, are tolerant of high Ca levels. Some 20 vegetable crops have been grown successfully on irrigated Calcisols fertilized with nitrogen, phosphorus and trace elements such as iron and zinc.

Furrow irrigation is superior to basin irrigation on slaking Calcisols because it reduces surface crusting/caking and seedling mortality; pulse crops in particular are vulnerable in the seedling stage. In places, arable farming is hindered by stoniness of the surface soil and/or a *petrocalcic* horizon at shallow depth.

CAMBISOLS

Cambisols combine soils with at least an incipient subsurface soil formation. Transformation of parent material is evident from structure formation and mostly brownish discoloration, increasing clay percentage, and/or carbonate removal. Other soil classification systems refer to many Cambisols as *Braunerden* and *Terrae fuscae* (Germany), *Sols bruns* (France), *burozems* (Russia) and *Tenosols* (Australia). The name *Cambisols* was coined for the Soil Map of the World (FAO–UNESCO, 1971–1981) and later adopted by Brazil (*Cambissolos*). In the United States of America they were formerly called *Brown soils/Brown forest soils* and are now named *Inceptisols*.

Summary description of Cambisols

Connotation: Soils with at least the beginnings of horizon differentiation in the subsoil, evident from changes in structure, colour, clay content or carbonate content; from Late Latin *cambiare*, to change.

Parent material: Medium and finetextured materials derived from a wide range of rocks.

Profile development: Cambisols are characterized by slight or moderate weathering of parent material and by absence of appreciable quantities of illuviated clay, organic matter, Al and/or Fe compounds. Cambisols also encompass soils that fail one or more characteristics diagnostic for other RSGs, including highly weathered ones.

Environment: Level to mountainous terrain in all climates; wide range of vegetation types.

Regional distribution of Cambisols

Cambisols cover an estimated 1 500 million ha worldwide. This RSG is particularly well represented in temperate and boreal regions that were under the influence of glaciations during the Pleistocene, partly because the parent material of the soil is still young, but also because soil formation is slow in cool regions. Erosion and deposition cycles explain the occurrence of Cambisols in mountain regions. Cambisols also occur in dry regions but are less common in the humid tropics and subtropics where weathering and soil formation proceed at much faster rates than in temperate, boreal and dry regions. The young alluvial plains and terraces of the Ganges–Brahmaputra system are probably the largest continuous surface of Cambisols in the tropics. Cambisols are also common in areas with active geologic erosion, where they may occur in association with mature tropical soils.

Management and use of Cambisols

Cambisols generally make good agricultural land and are used intensively. Cambisols with high base saturation in the temperate zone are among the most productive soils on earth. More acid Cambisols, although less fertile, are used for mixed arable farming and as grazing and forest land. Cambisols on steep slopes are best kept under forest; this is particularly true for Cambisols in highlands.

Cambisols on irrigated alluvial plains in the dry zone are used intensively for production of food and oil crops. Cambisols in undulating or hilly terrain are planted with a variety of annual and perennial crops or are used as grazing land.

Cambisols in the humid tropics are typically poor in nutrients but are still richer than associated Acrisols or Ferralsols, and they have a greater CEC. Cambisols with groundwater influence in alluvial plains are highly productive *paddy soils*.

CHERNOZEMS

Chernozems accommodate soils with a thick blackish mineral surface layer that is rich in organic matter. The Russian soil scientist V.V. Dokuchaev coined the name *Chernozem* in 1883 to denote the typical soils of the tall-grass steppes in continental Russia. Many Chernozems correspond to *Kalktschernoseme* (Germany), *Chernosols* (France), *Eluviated black soils* (Canada) and *Chernossolos* (Brazil). In the United States of America they were formerly called *Calcareous black soils* and belong now to several Suborders (especially *Udolls*) of the *Mollisols*.

Summary description of Chernozems

Connotation: Blackish soils rich in organic matter; from Russian *chorniy*, black, and *zemlya*, earth or land.

Parent material: Mostly aeolian and reworked aeolian sediments (loess).

Environment: Regions with a continental climate with cold winters and hot summers, which are dry at least in late summer; in flat to undulating plains with tall-grass vegetation (hardwood forest especially in the northern transitional zone).

Profile development: Blackish *chernic* surface horizon, in many cases over a *cambic* or *argic* horizon; with secondary carbonates (*protocalcic* properties or *calcic* horizon) in the subsoil.

Regional distribution of Chernozems

Chernozems cover an estimated 230 million ha worldwide, mainly in the mid-latitude steppes of Eurasia (north of the zone with Kastanozems) and North America.

Management and use of Chernozems

Russian soil scientists rank the deep, central Chernozems among the best soils in the world. With less than half of all Chernozems in Eurasia being used for arable cropping, these soils constitute a formidable resource for the future. Preservation of the favourable soil structure through timely cultivation and careful irrigation at low watering rates prevent wind and water erosion. Application of P fertilizers is required for high yields. Wheat, barley and maize are the principal crops grown, alongside other food crops and vegetables. Part of the Chernozem area is used for livestock rearing. In the northern temperate belt, the possible growing period is short and the principal crops grown are wheat and barley, in places in rotation with vegetables. Maize and sunflower are widely grown in the warm temperate belt. Maize production tends to stagnate in drier years unless the crop is irrigated adequately.

CRYOSOLS

Cryosols comprise mineral soils formed in a permafrost environment. The subsurface layers (*cryic* horizon) are permanently frozen, and if present, water occurs in the form of ice. Cryogenic processes are the dominant soil-forming processes in most Cryosols. Cryosols are widely known as *Permafrost soils, Cryomorphic soils* or *Polar desert soils*. Other common names for many Cryosols are *Gelisols* (United States of America) and *Cryozems* (Russia).

Summary description of Cryosols

Connotation: Frost-affected soils; from Greek *kryos*, cold.

Parent material: A wide variety of materials, including glacial till and aeolian, alluvial, colluvial and residual materials.

Environment: Flat to mountainous areas in Antarctic, Arctic, subarctic and boreal regions affected by permafrost. Cryosols are associated with sparsely to continuously vegetated tundra, open-canopy lichen coniferous forest (dominated by larch) and closed-canopy coniferous or mixed coniferous deciduous forest.

Profile development: In the presence of water, cryogenic processes produce cryoturbated horizons, frost heave, thermal cracking, ice segregation and patterned ground microrelief.

Regional distribution of Cryosols

Geographically, Cryosols are circumpolar in both the Northern and Southern Hemispheres. They cover an estimated 1 800 million ha or about 13 percent of the global land surface. Cryosols are widespread in the Arctic, subarctic and boreal zone and sporadic in more temperate mountainous regions. Major areas with Cryosols are found in the Russian Federation (1 000 million ha), Canada (250 million ha), China (190 million ha), Alaska (110 million ha) and in parts of Mongolia. Smaller occurrences have been reported from northern Europe, Greenland and the ice-free areas of Antarctica.

Management and use of Cryosols

Natural and human-induced biological activity in Cryosols is confined to the active surface layer that thaws every summer and also protects the underlying permafrost.

Removal of the peat layer on top of the soil or of the vegetation and/or disturbance of the surface soil often lead to alterations of the permafrost depth and to rapid and drastic environmental changes with possible damage to buildings.

Most areas of Cryosols in North America and Eurasia are in the natural state and support sufficient vegetation for grazing animals, such as caribou, reindeer and musk oxen. Large herds of caribou still migrate seasonally in the northern part of North America; reindeer herding is an important industry in the vast northern areas, especially in northern Europe. Overgrazing leads rapidly to erosion and other environmental damage.

Human activities, mainly relating to agriculture, oil and gas production and mining, have had a major impact on these soils. Severe *thermokarst* has occurred on land cleared for agriculture. Improper management of pipelines and mining can cause oil spills and a chemical pollution of large areas.

DURISOLS

Durisols are associated mainly with old surfaces in arid and semi-arid environments and accommodate shallow to moderately deep, moderately well- to well-drained soils that contain cemented secondary silica (SiO_2) within 100 cm of the soil surface. Many Durisols are known as *Hardpan soils* or *Duric Kandosols* (Australia), *Dorbank* (South Africa), or *Durids* (United States of America). In the Soil Map of the World (FAO–UNESCO, 1971–1981) they are the *Duripan phases* of other soils, e.g. of *Calcisols*.

Summary description of Durisols

Connotation: Soils with hardened secondary silica; from Latin *durus*, hard.

Parent material: Silicate-rich materials, mainly alluvial and colluvial deposits of all texture classes.

Environment: Level and slightly sloping alluvial plains, terraces and gently sloping piedmont plains in arid, semi-arid and Mediterranean regions.

Profile development: Strongly weathered soils with a hard layer of secondary silica (*petroduric* horizon) or nodules of secondary silica (*duric* horizon); eroded Durisols with exposed *petroduric* horizons are common in gently sloping terrain.

Regional distribution of Durisols

Extensive areas of Durisols occur in Australia, in South Africa and Namibia and in the United States of America (notably Nevada, California and Arizona); minor occurrences have been reported from Mexico, Central and South America and from Kuwait. Durisols have only recently been introduced into international soil classifications and have not often been mapped as such. A precise indication of their extent is not yet available.

Management and use of Durisols

The agricultural use of Durisols is limited to extensive grazing (rangeland). Durisols in natural environments generally support enough vegetation to contain erosion, but elsewhere erosion of the surface soil is widespread.

Stable landscapes occur in dry regions where Durisols were eroded down to their resistant *petroduric* horizon. Durisols may be cultivated with some success where sufficient irrigation water is available. A *petroduric* horizon may need to be broken up or removed altogether if it forms a barrier to root and water penetration. Excess levels of soluble salts may affect Durisols in low-lying areas. Pieces of *petroduric* horizons are widely used in road construction.

FERRALSOLS

Ferralsols represent the classical, deeply weathered, red or yellow soils of the humid tropics. These soils have diffuse horizon boundaries, a clay assemblage dominated by low-activity clays (mainly kaolinite) and a high content of sesquioxides. Local names usually refer to the colour of the soil. Many Ferralsols are known as *Oxisols* (United States of America), *Latossolos* (Brazil), *Alítico*, *Ferrítico* and *Ferralítico* (Cuba), *Kandosols* (Australia), *Sols ferralitiques* (France) and *Ferralitic soils* (Russia).

Summary description of Ferralsols

Connotation: Red and yellow tropical soils with a high content of sesquioxides; from Latin *ferrum*, iron, and *alumen*, alum.

Parent material: Strongly weathered material on old, stable geomorphic surfaces; develop faster in material weathered from basic rock than from siliceous material.

Environment: Typically in level to undulating land of Pleistocene age or older; less common on younger, easily weathering rocks. Perhumid or humid tropics; minor occurrences elsewhere are considered to be relics from past eras with a warmer and wetter climate than today.

Profile development: Deep and intensive weathering has resulted in a residual concentration of resistant primary minerals (e.g. quartz) along with sesquioxides and kaolinite. This mineralogy and the relatively low pH explain the stable microstructure (pseudo-sand) and yellowish (goethite) or reddish (hematite) soil colours.

Regional distribution of Ferralsols

The worldwide extent of Ferralsols is estimated at some 750 million ha, almost exclusively in the humid tropics on the continental shields of South America (especially Brazil) and Africa (especially Congo, Democratic Republic of the Congo, southern Central African Republic, Angola, Guinea and eastern Madagascar). Outside the continental shields, Ferralsols are restricted to regions with easily weathering basic rock and a hot and humid climate, e.g. in Southeast Asia.

Management and use of Ferralsols

Most Ferralsols have good physical properties. Great soil depth, good permeability and stable microstructure make Ferralsols less susceptible to erosion than most other intensely weathered tropical soils. Moist Ferralsols are friable and easy to work. They are well drained but may at times be droughty because of their low available water storage capacity.

The chemical fertility of Ferralsols is poor; weatherable minerals are scarce or absent, and cation retention by the mineral soil fraction is weak. Under natural vegetation, nutrient elements that are taken up by the roots from greater depths are eventually returned to the surface soil with falling leaves and other plant debris. The bulk of all cycling plant nutrients are contained in the biomass; available plant nutrients in the soil are concentrated in the soil organic matter. If the process of *nutrient cycling* is interrupted, e.g. upon introduction of low-input sedentary subsistence farming, the topsoil will rapidly become depleted of plant nutrients.

Maintaining soil fertility by manuring, mulching and/or adequate (i.e. long enough) fallow periods or agroforestry practices, and prevention of surface soil erosion, are important management requirements.

Strong retention (fixing) of P is a characteristic problem in Ferralsols (and several other soils, e.g. Andosols). Ferralsols are normally also low in base cations and some 20 micronutrients. Silicon deficiency is possible where silicon-demanding crops (e.g. grasses) are grown. In Mauritius, soils are tested for available silicon and fertilized with silicon amendments. Manganese and zinc, which are very soluble at low pH, may at some time reach toxic levels in the soil or become deficient after intense leaching of the soil. Boron and copper deficiencies may also be encountered.

In Ferralsols with a low pH, liming is a means of raising the pH of the rooted surface soil. Liming combats Al toxicity and raises the effective CEC. On the other hand, it lowers the anion exchange capacity, which may lead to collapse of microstructural elements and slaking at the soil surface. Therefore, frequent small doses of lime or basic slag are preferable to one massive application; 0.5–2 tonnes/ha of lime or dolomite are normally enough to supply Ca as a nutrient and to buffer the low soil pH of many Ferralsols. Surface application of gypsum, as a suitably mobile form of Ca, can increase the depth of crop root development (in addition, the sulfate in the gypsum reacts with sesquioxides to produce a "self-liming" effect). This relatively recent innovation is now practised widely, especially in Brazil.

Fertilizer selection and the mode and timing of fertilizer application determine to a great extent the success of agriculture on Ferralsols. Slow-release phosphate (phosphate rock) applied at a rate of several tonnes per hectare eliminates P deficiency for a number of years. For a quick fix, much more soluble double or triple superphosphate is used, needed in much smaller quantities, especially if placed in the direct vicinity of the roots.

Sedentary subsistence farmers and shifting cultivators on Ferralsols grow a variety of annual and perennial crops. Extensive grazing is also common and considerable areas of Ferralsols are not used for agriculture at all. The good physical properties of Ferralsols and the often level topography would encourage more intensive forms of land use if problems caused by poor chemical properties could be overcome.

FLUVISOLS

Fluvisols accommodate genetically young soils in fluvial, lacustrine or marine deposits. Despite their name, *Fluvisols* are not restricted to *river* sediments (Latin *fluvius*, river); they also occur in lacustrine and marine deposits. Many Fluvisols correlate with *Alluvial soils* (Russia), *Stratic Rudosols* (Australia), *Fluvents* (United States of America), *Auenböden* (Germany), *Neossolos* (Brazil), and *Sols minéraux bruts d'apport alluvial ou colluvial* or *Sols peu évolués non climatiques d'apport alluvial ou colluvial*

(France). The position of Fluvisols in the key was changed several times during history of FAO and WRB classification systems. The current 3rd edition of WRB puts them further down and shifts some former Fluvisols to other RSGs, especially to *Solonchaks* and *Gleysols*.

Summary description of Fluvisols

Connotation: Soils developed in fluvial deposits; from Latin *fluvius*, river.

Parent material: Predominantly recent, fluvial, lacustrine and marine deposits.

Environment: River plains and fans, valleys, lake depressions and tidal marshes on all continents and in all climate zones; no groundwater and no high salt contents in the topsoil; many Fluvisols under natural conditions are flooded periodically.

Profile development: Profiles with evidence of stratification; weak horizon differentiation but a distinct topsoil horizon may be present.

Regional distribution of Fluvisols

Fluvisols occur on all continents and in all climates. They occupy less than 350 million ha worldwide, of which more than half are in the tropics. Major areas of Fluvisols are found:

- along rivers and lakes, e.g. in the Amazon basin, the plains near Lake Chad in Central Africa, the Ganges Plain of India and in eastern China;
- in deltaic areas, e.g. the deltas of the Indus, Ganges–Brahmaputra, Mekong, Lena, Nile, Niger, Zambezi, Mississippi, Orinoco, Plate, Volga, Po and Rhine;
- • in areas of recent marine deposits, for example the coastal lowlands of Indonesia (e.g. Sumatra, Kalimantan and Papua province) and Papua New Guinea.

Management and use of Fluvisols

The good natural fertility of most Fluvisols and attractive dwelling sites on river levees and on higher parts in marine landscapes were recognized in prehistoric times. Later, great civilizations developed in river landscapes and on marine plains.

Paddy rice cultivation is widespread on tropical Fluvisols with satisfactory irrigation. Paddy land should be dry for at least a few weeks every year in order to prevent the redox potential of the soil from becoming so low that nutritional problems (Fe or H_2S) arise. A dry period also stimulates microbial activity and promotes mineralization of organic matter. Many dryland crops are grown on Fluvisols as well, normally with some form of water control.

GLEYSOLS

Gleysols comprise soils saturated with groundwater for long enough periods to develop *reducing conditions* resulting in *gleyic* properties, including underwater and tidal soils. This pattern is essentially made up of reddish, brownish or yellowish colours at aggregate surfaces and/or in the upper soil layers, in combination with greyish/bluish colours inside the aggregates and/or deeper in the soil. Many underwater soils have only the latter. Gleysols with a *thionic* horizon or *hypersulfidic* material (a*cid sulfate soils*) are common. Redox processes may also be caused by upmoving gases, like CO_2 or CH_4. Common names for many Gleysols are *Gley* (former Soviet Union), *Gleyzems* (Russia), *Gleye*, *Marschen*, *Watten* and *Unterwasserböden* (Germany), *Gleissolos* (Brazil) and *Hydrosols* (Australia). In the United States of America many Gleysols belong to Aquic Suborders and Endoaquic Great Groups of various Orders (*Aqualfs*, *Aquents*, *Aquepts*, *Aquolls*, etc.) or to the *Wassents*.

Summary description of Gleysols

Connotation: Soils with clear signs of groundwater influence; from Russian *gley* (as soil name introduced by G.N. Vysotskiy in 1905), mucky mass.

Parent material: A wide range of unconsolidated materials, mainly fluvial, marine and lacustrine sediments.

Environment: Low positions in landscapes with high groundwater table, tidal areas, shallow lakes and sea shores.

Profile development: Evidence of reduction processes with segregation of Fe compounds starting within 40 cm of the soil surface.

Regional distribution of Gleysols

Gleysols occupy more than 720 million ha worldwide. They occur at all latitudes and in nearly all climates, from perhumid to arid. The largest extent of Gleysols is in subarctic areas in the north of the Russian Federation, Canada and Alaska, and in humid temperate and subtropical lowlands, e.g. in China and Bangladesh. An estimated 200 million ha of Gleysols are found in the tropics, mainly in the Amazon region, equatorial Africa and the coastal swamps of Southeast Asia. Larger tidal areas are found along the coast of the North Sea.

Major areas of Gleysols with a *thionic* horizon or *hypersulfidic* material (a*cid sulfate soils*) are found in the coastal lowlands of Southeast Asia (Indonesia, Viet Nam and Thailand), West Africa (Senegal, Gambia, Guinea Bissau, Sierra Leone and Liberia) and along the northeast coast of South America (French Guiana, Guyana, Suriname and Venezuela).

Management and use of Gleysols

For many Gleysols, the main obstacle to utilization is the necessity to install a drainage system to lower the groundwater table. Adequately drained Gleysols can be used for arable cropping, dairy farming and horticulture. Soil structure will be destroyed for a long time if soils are cultivated when too wet. Therefore, Gleysols in depression areas with unsatisfactory possibilities to lower the groundwater table are best kept under a permanent grass cover or swamp forest. Liming of drained Gleysols that are high in organic matter and/or of low pH value creates a better habitat for micro- and meso-organisms and enhances the rate of decomposition of soil organic matter (and the supply of plant nutrients).

Gleysols can be put under tree crops only after the water table has been lowered with deep drainage ditches. Alternatively, the trees are planted on ridges that alternate with shallow depressions in which rice is grown. This *sorjan* system is applied widely in tidal swamp areas with pyretic sediments in Southeast Asia. Gleysols can be used for wetland rice cultivation where the climate is appropriate. Gleysols with a *thionic* horizon or oxidized *hypersulfidic* material suffer from severe acidity and high levels of Al toxicity.

Underwater and tidal Gleysols are used for fishing or shrimp production. Many are left under natural conditions. Tidal lands that are strongly saline are best kept under mangroves or some other salt-tolerant vegetation. Such areas are ecologically valuable and can, with caution, be used for fishing, hunting, salt pans or woodcutting for charcoal or fuelwood.

GYPSISOLS

Gypsisols are soils with substantial accumulation of secondary gypsum ($CaSO_4{\cdot}2H_2O$). These soils are found in the driest parts of the arid climate zone, which explains why leading soil classification systems labelled many of them *Desert grey-brown soils* (former Soviet Union). The Soil Map of the World (FAO–UNESCO, 1971–1981) accommodates them among *Yermosols* or *Xerosols*. In the United States of America most of them belong to the *Gypsids*.

Summary description of Gypsisols

Connotation: Soils with substantial accumulation of secondary calcium sulfate; from Greek *gypsos*, gypsum.

Parent material: Mostly unconsolidated deposits of base-rich weathering material.

Environment: Predominantly level to hilly land and depression areas (e.g. former inland lakes) in regions with an arid climate. The natural vegetation is sparse and dominated by xerophytic shrubs and trees and/or ephemeral grasses and herbs.

Profile development: Light-coloured surface horizon; accumulation of calcium sulfate, with or without carbonates, in the subsoil.

Regional distribution of Gypsisols

Gypsisols are restricted to arid regions; their worldwide extent is probably of the order of 100 million ha. Major occurrences are in the Near East, Kazakhstan, Turkmenistan, Uzbekistan, in the Libyan and Namib deserts, in southern and central Australia and in the southwest of the United States of America.

Management and use of Gypsisols

Gypsisols that contain only a low percentage of gypsum in the upper 30 cm can be used for the production of small grains, cotton, alfalfa, etc. Dry farming on deep Gypsisols makes use of fallow years and other water harvesting techniques but is rarely very rewarding because of the adverse climate conditions. Gypsisols in young deposits have a relatively low gypsum content. Where such soils are in the vicinity of water resources, they can be very productive; many irrigation projects are established on such soils. However, even soils containing 25 percent powdery gypsum or more could still produce excellent yields of alfalfa hay (10 tonnes/ha), wheat, apricots, dates, maize and grapes if irrigated at high rates in combination with forced drainage. Irrigated agriculture on Gypsisols is plagued by rapid dissolution of soil gypsum, resulting in irregular subsidence of the land surface, caving in canal walls and corrosion of concrete structures. Large areas with Gypsisols are used for extensive grazing.

HISTOSOLS

Histosols comprise soils formed in *organic* material accumulating as groundwater peat (fen), rainwater peat (raised bog) or mangroves or without water saturation in cool mountain areas. They vary from soils developed in predominantly moss peat in arctic, subarctic and boreal regions, via moss peat (*Sphagnum* species), reeds/sedge peat (fen) and forest peat in temperate regions to mangrove peat and swamp forest peat in the humid tropics. Histosols are found at all altitudes, but the vast majority occurs in lowlands. Common names are *Peat soils*, *Muck soils*, *Bog soils* and *Organic soils*. Many Histosols belong to *Moore*, *Felshumusböden* and *Skeletthumusböden* (Germany), *Organosols* (Australia), *Organossolos* (Brazil), *Peat soils* (Russia), *Organic order* (Canada) and *Histosols* and *Histels* (United States of America).

Summary description of Histosols

Connotation: Peat and muck soils; from Greek *histos*, tissue.

Parent material: Incompletely decomposed plant remains, with or without admixtures of sand, silt or clay.

Environment: Histosols occur extensively in boreal, subarctic and arctic regions. Elsewhere they are confined to poorly drained basins and depressions, swamps and marshlands with shallow groundwater and cool highland areas with a high precipitation–evapotranspiration ratio.

Profile development: Mineralization is slow and transformation of plant residues through biochemical disintegration and formation of humic substances creates a surface layer of mould with or without prolonged water saturation.

Regional distribution of Histosols

The total extent of Histosols in the world is estimated at some 325–375 million ha, the majority located in the boreal, subarctic and low arctic regions of the Northern Hemisphere. Most of the remaining Histosols occur in temperate lowlands and cool montane areas; only one-tenth of all Histosols are found in the tropics. Extensive areas of Histosols occur in the United States of America and Canada, Western Europe and northern Scandinavia and in the West Siberian Plain. Some 20 million ha of tropical forest peat border the Sunda shelf in Southeast Asia. Smaller areas of tropical Histosols are found in river deltas, e.g. in the Orinoco Delta and the delta of the River Mekong and in depression areas at some altitude.

Management and use of Histosols

The properties of the *organic* material (botanical composition, stratification, degree of decomposition, packing density, wood content, mineral admixtures, etc.) and the type of peat (basin peat [fen], raised bog, etc.) determine the management requirements and land use possibilities of Histosols. Histosols without prolonged water saturation are often formed in cold environments unattractive for agricultural use. Natural peats need to be drained, and normally also limed and fertilized in order to permit cultivation of normal crops. Centrally guided reclamation projects in the temperate zone have opened up millions of hectares. In many instances, this has initiated the gradual degradation, and ultimately the loss of the precious peat. In the tropics, increasing numbers of landless farmers venture onto the peat lands, where they clear the forest and cause raging peat fires in the process. Many of them abandon their land again after only a few years; the few that succeed are on thin, topogenous peat. In recent decades, increasing areas of tropical peat land have been planted with oil-palm and pulp wood tree species such as *Acacia mangium*, *Acacia crassicarpa* and *Eucalyptus* spp. This practice may be less than ideal but it is far less destructive than arable subsistence farming.

Another common problem encountered when Histosols are drained is the oxidation of sulfidic minerals, which accumulate under anaerobic conditions, especially in coastal regions. The sulfuric acid produced effectively destroys productivity unless lime is applied copiously, making the cost of reclamation prohibitive.

In summary, it is desirable to protect and conserve fragile peat lands because of their intrinsic value (especially their common function as sponges in regulating stream flow and in supporting wetlands containing unique species of animals) and because prospects for their sustained agricultural use are meagre. Where their use is imperative, sensible forms of forestry or plantation cropping are preferred over annual cropping, horticulture, or, the worst option, harvesting of the peat material for power generation or production of horticultural growth substrate, active carbon, flower pots, etc. Peat that is used for arable crop production will mineralize at sharply increased rates because it must be drained, limed and fertilized in order to ensure satisfactory crop growth. Under these circumstances, the drain depth should be kept as shallow as possible and prudence exercised when applying lime and fertilizers.

KASTANOZEMS

Kastanozems accommodate dry grassland soils, among them the soils of the short-grass steppe belt, south of the Eurasian tall-grass steppe belt with Chernozems. Kastanozems have a similar profile to that of Chernozems but the humus-rich surface horizon is thinner and not as dark as that of the Chernozems, and they show more prominent accumulation of secondary carbonates. The chestnut-brown colour of the surface soil is reflected in the name *Kastanozem*. Common names for many Kastanozems are *(Dark) Chestnut soils* (Russia), *Kalktschernoseme* (Germany), *(Dark) Brown soils* (Canada), *Ustolls* and *Xerolls* (United States of America) and *Chernossolos* (Brazil).

Summary description of Kastanozems

Connotation: Dark brown soils rich in organic matter; from Latin *castanea* and Russian *kashtan*, chestnut, and Russian *zemlya*, earth or land.

Parent material: A wide range of unconsolidated materials; a large part of Kastanozems has developed in loess.

Environment: Dry and continental with relatively cold winters and hot summers; flat to undulating grasslands dominated by ephemeral short grasses.

Profile development: A brown *mollic* horizon of medium thickness, in many cases over a brown to cinnamon *cambic* or *argic* horizon; with secondary carbonates (*protocalcic* properties or *calcic* horizon) in the subsoil, in some cases also with secondary gypsum.

Regional distribution of Kastanozems

The total extent of Kastanozems is estimated to be about 465 million ha. Major areas are in the Eurasian short-grass steppe belt (southern Ukraine, the south of the Russian Federation, Kazakhstan and Mongolia), in the Great Plains of the United States of America, Canada and Mexico, and in the pampas and chaco regions of northern Argentina, Paraguay and southeastern Bolivia.

Management and use of Kastanozems

Kastanozems are potentially rich soils; periodic lack of soil moisture is the main obstacle to high yields. Irrigation is nearly always necessary for high yields; care must be taken to avoid secondary salinization. Phosphate fertilizers might be necessary for good yields. Small grains and irrigated food and vegetable crops are the principal crops grown. Wind and water erosion is a problem on Kastanozems, especially on fallow lands.

Extensive grazing is another important land use on Kastanozems. However, the sparsely vegetated grazing lands are inferior to the tall-grass steppes on Chernozems, and overgrazing is a serious problem.

LEPTOSOLS

Leptosols comprise very thin soils over continuous rock and soils that are extremely rich in coarse fragments. Leptosols are particularly common in mountainous regions. Leptosols include *Lithosols* of the Soil Map of the World (FAO–UNESCO, 1971–1981), *Lithic* subgroups of the *Entisol* Order (United States of America), *Leptic Rudosols* or *Tenosols* (Australia), and *Petrozems* and *Litozems* (Russia). In many national systems and in the Soil Map of the World, Leptosols on calcareous rocks belong to *Rendzinas* and those on other rocks to *Rankers*. Continuous rock at the surface is considered non-soil in many soil classification systems.

Summary description of Leptosols

Connotation: Thin soils; from Greek *leptos*, thin.

Parent material: Various kinds of continuous rock or of unconsolidated materials with less than 20 percent (by volume) fine earth.

Environment: Mostly land at high or medium altitude and with strongly dissected topography. Leptosols are found in all climate zones (many of them in hot or cold dry regions), in particular in strongly eroding areas.

Profile development: Leptosols have continuous rock at or very close to the surface or are extremely gravelly. Leptosols in weathered calcareous material may have a *mollic* horizon.

Regional distribution of Leptosols

Leptosols are the most extensive RSG on earth, extending over about 1 655 million ha. Leptosols are found from the tropics to the polar regions and from sea level to the highest mountains. Leptosols are particularly widespread in montane areas, notably in Asia and South America, in the Sahara and the Arabian deserts, the Ungava Peninsula of northern Canada and in the Alaskan mountains. Elsewhere, Leptosols can be found on rocks that are resistant to weathering or where erosion has kept pace with soil formation or has removed the top of the soil profile. Leptosols with *continuous rock* at less than 10 cm depth in montane regions are the most extensive Leptosols.

Management and use of Leptosols

Leptosols have a resource potential for wet-season grazing and as forest land. Leptosols to which the Rendzic qualifier applies are planted with teak and mahogany in Southeast Asia; those in the temperate zone are under mainly deciduous mixed forest whereas acid Leptosols are commonly under coniferous forest. Erosion is the greatest threat to Leptosol areas, particularly in montane regions in the temperate zones where high population pressure (tourism), overexploitation and increasing environmental pollution lead to deterioration of forests. Leptosols on hill slopes are generally more fertile than their counterparts on more level land. One or a few good crops could perhaps be grown on such slopes but at the price of severe erosion. Steep slopes with thin and stony soils can be transformed into cultivable land through terracing, the removal of stones by hand and their use as terrace fronts. Agroforestry (a combination or rotation of arable crops and trees under strict control) holds promise but is still largely in an experimental stage. The excessive internal drainage and the shallow depth of many Leptosols can cause drought even in a humid environment.

LIXISOLS

Lixisols have a higher clay content in the subsoil than in the topsoil, as a result of pedogenetic processes (especially clay migration) leading to an *argic* subsoil horizon. Lixisols have low-activity clays in the *argic* horizon and a high base saturation in the 50–100 cm depth. Many Lixisols are included in *Red yellow podzolic soils* (e.g. Indonesia), *Chromosols* (Australia), *Argissolos* (Brazil), *Sols ferralitiques faiblement desaturés appauvris* (France) and *Alfisols* with low-activity clays (United States of America).

Summary description of Lixisols

Connotation: Soils with a pedogenetic clay differentiation (especially clay migration) between a topsoil with a lower and a subsoil with a higher clay content, low-activity clays and a high base saturation at some depth; from Latin *lixivia*, washed-out substances.

Parent material: In a wide variety of parent materials, notably in unconsolidated, chemically strongly weathered, fine textured materials.

Environment: Regions with a tropical, subtropical or warm temperate climate with a pronounced dry season. Many Lixisols are surmised to be polygenetic soils with characteristics formed under a more humid climate in the past.

Profile development: Pedogenetic differentiation of clay content, with a lower content in the topsoil and a higher content in the subsoil; weathering advanced without a marked loss of base cations. The loss of iron oxides together with clay minerals may lead to a bleached eluviation horizon between the surface horizon and the *argic* subsurface horizon but Lixisols lack the *retic* properties of the Retisols.

Regional distribution of Lixisols

Lixisols are found in seasonally dry tropical, subtropical and warm temperate regions on Pleistocene and older surfaces. These soils cover a total area of about 435 million ha, of which more than half occur in (sub-)Sahelian and East Africa, about one-quarter in South and Central America, and the remainder on the Indian subcontinent and in Southeast Asia and Australia.

Management and use of Lixisols

Areas with Lixisols that are still under savannah or open woodland vegetation are widely used for low volume grazing. Preservation of the surface soil with its all-important organic matter is of utmost importance. Degraded surface soils have low aggregate stability and are prone to slaking and/or erosion where exposed to the direct impact of raindrops. Tillage of wet soil or use of excessively heavy machinery compacts the soil and causes serious structure deterioration. Tillage and erosion control measures such as terracing, contour ploughing, mulching and use of cover crops help to conserve the soil. The low absolute level of plant nutrients and the low cation retention by Lixisols makes recurrent inputs of fertilizers a precondition for continuous cultivation. Chemically and/or physically deteriorated Lixisols regenerate very slowly where not reclaimed actively.

Perennial crops are to be preferred to annual crops, particularly on sloping land. Cultivation of tuber crops (cassava and sweet potato) or groundnut increases the danger of soil deterioration and erosion. Rotation of annual crops with improved pasture has been recommended to maintain or improve the content of soil organic matter.

LUVISOLS

Luvisols have a higher clay content in the subsoil than in the topsoil, as a result of pedogenetic processes (especially clay migration) leading to an *argic* subsoil horizon. Luvisols have high-activity clays throughout the *argic* horizon and a high base saturation in the 50–100 cm depth. Many Luvisols are known as *Texturally-differentiated soils* and part of *Metamorphic soils* (Russia), *Sols lessivés* (France), *Parabraunerden* (Germany), *Chromosols* (Australia) and *Luvissolos* (Brazil). In the United States of America, they were formerly named *Grey-brown podzolic soils* and belong now to the *Alfisols* with high-activity clays.

Summary description of Luvisols

Connotation: Soils with a pedogenetic clay differentiation (especially clay migration) between a topsoil with a lower and a subsoil with a higher clay content, high-activity clays and a high base saturation at some depth; from Latin e*luere*, to wash.

Parent material: A wide variety of unconsolidated materials including glacial till, and aeolian, alluvial and colluvial deposits.

Environment: Most common in flat or gently sloping land in cool temperate regions and in warm regions (e.g. Mediterranean) with distinct dry and wet seasons.

Profile development: Pedogenetic differentiation of clay content, with a lower content in the topsoil and a higher content in the subsoil without marked leaching of base cations or advanced weathering of high-activity clays. The loss of iron oxides together with clay minerals may lead to a bleached eluviation horizon between the surface horizon and the *argic* subsurface horizon but Luvisols lack the *retic* properties of the Retisols.

Regional distribution of Luvisols

Luvisols extend over 500–600 million ha worldwide, mainly in temperate regions such as in the East European Plain and parts of the West Siberian Plain, the North-East of the United States of America, and Central Europe, but also in the Mediterranean region and southern Australia. In subtropical and tropical regions, Luvisols occur mainly on young land surfaces.

Management and use of Luvisols

Most Luvisols are fertile soils and suitable for a wide range of agricultural uses. Luvisols with a high silt content are susceptible to structure deterioration where tilled when wet or with heavy machinery. Luvisols on steep slopes require erosion control measures. In places, the dense subsoil causes temporarily *reducing conditions* with *stagnic* properties.

Luvisols in the temperate zone are widely sown with small grains, sugar beet and fodder; in sloping areas, they are used for orchards, forests and/or grazing. In the Mediterranean region, where Luvisols (many with the Chromic, Calcic or Vertic qualifier) are common in colluvial deposits of limestone weathering, the lower slopes are widely sown with wheat and/or sugar beet while the often eroded upper slopes are used for extensive grazing or planted with tree crops.

NITISOLS

Nitisols are deep, well-drained, red tropical soils with diffuse horizon boundaries and a subsurface horizon with at least 30 percent clay and moderate to strong angular blocky structure breaking into polyhedral or flat-edged or nut-shaped elements with, in moist state, shiny aggregate faces. Weathering is relatively advanced but Nitisols are far more productive than most other red tropical soils. Many Nitisols correlate with *Nitossolos* (Brazil), *Kandic* Great Groups of *Alfisols* and *Ultisols* and different Great Groups of *Inceptisols* and *Oxisols* (United States of America), *Sols fersialitiques* or *Ferrisols* (France) and *Ferrosols* (Australia).

Summary description of Nitisols

Connotation: Deep, well-drained, red tropical soils with a clayey *nitic* horizon that has typical angular blocky structure breaking into polyhedral or flat-edged or nut-shaped elements with, in moist state, shiny aggregate faces; from Latin *nitidus*, shiny.

Parent material: Finely textured weathering products of intermediate to basic parent rock, in some regions rejuvenated by recent admixtures of volcanic ash.

Environment: Nitisols are predominantly found on level to hilly land under tropical rainforest or savannah vegetation.

Profile development: Red or reddish-brown clayey soils with a *nitic* subsurface horizon of high aggregate stability. The clay assemblage of Nitisols is dominated by kaolinite/(meta) halloysite. Nitisols are rich in Fe and have little water-dispersible clay.

Regional distribution of Nitisols

There are about 200 million ha of Nitisols worldwide. More than half of all Nitisols are found in tropical Africa, notably in the highlands (> 1 000 m) of Ethiopia, Kenya, Congo and Cameroon. Elsewhere Nitisols are well represented at lower altitudes, e.g. in tropical Asia, South America, Central America, Southeast Africa and Australia.

Management and use of Nitisols

Nitisols are among the most productive soils of the humid tropics. The deep and porous solum and the stable soil structure of Nitisols permit deep rooting and make these soils quite resistant to erosion. The good workability of Nitisols, their good internal drainage and fair water holding properties are complemented by chemical (fertility) properties that compare favourably with those of most other tropical soils. Nitisols have relatively high contents of weathering minerals, and surface soils may contain several percent of organic matter, in particular under forest or tree crops. Nitisols are planted with plantation crops, such as cocoa, coffee, rubber and pineapple and are also widely used for food crop production on smallholdings. High P sorption calls for application of P fertilizers, usually provided as slow-release, low-grade phosphate rock (several tonnes per hectare, with maintenance doses every few years) in combination with smaller applications of better soluble superphosphate for short-term response by the crop.

PHAEOZEMS

Phaeozems accommodate soils of relatively wet grassland and forest regions in moderately continental climates. Phaeozems are much like Chernozems and Kastanozems but are leached more intensively. Consequently, they have dark, humus-rich surface horizons that, in comparison with Chernozems and Kastanozems, are less rich in bases. Phaeozems are either free of secondary carbonates or have them only at greater depths. They all have a high base saturation in the upper metre of the soil. Commonly used names for many Phaeozems are *Brunizems* (Argentina and France), *Dark grey forest soils* and *Leached* and *Podzolized chernozems* (former Soviet Union), *Tschernoseme* (Germany) and *Chernossolos* (Brazil). In the Soil Map of the World (FAO–UNESCO, 1971–1981) they belong to the *Phaeozems* and partly to the *Greyzems*. *Dusky-red prairie soils* was their name in older systems of the United States of America, where most of them now belong to *Udolls* and *Albolls*.

Summary description of Phaeozems

Connotation: Dark soils rich in organic matter; from Greek *phaios*, dusky, and Russian *zemlya*, earth or land.

Parent material: Aeolian (loess), glacial till and other unconsolidated, predominantly basic materials.

Environment: Warm to cool (e.g. tropical highlands) moderately continental regions, humid enough that there is, in most years, some percolation through the soil, but also with periods in which the soil dries out; flat to undulating land; the natural vegetation is grassland such as tall-grass steppe and/or forest.

Profile development: A *mollic* horizon, or less widespread, a *chernic* horizon (thinner and in many soils less dark than in Chernozems), mostly over a *cambic* or *argic* subsurface horizon.

Regional distribution of Phaeozems

Phaeozems cover an estimated 190 million ha worldwide. Some 70 million ha of Phaeozems are found in the humid and subhumid Central Lowlands and easternmost parts of the Great Plains of the United States of America. Another 50 million ha of Phaeozems are in the subtropical pampas of Argentina and Uruguay. The third largest area of Phaeozems (18 million ha) is in northeastern China, followed by discontinuous areas in the centre of the Russian Federation. Smaller, mostly discontinuous areas are found in Central Europe, notably the Danube area of Hungary and adjacent countries and in montane areas in the tropics.

Management and use of Phaeozems

Phaeozems are porous, fertile soils and make excellent farmland. In the United States of America and Argentina, Phaeozems are in use for the production of soybean and wheat (and other small grains). Irrigated Phaeozems on the high plains of Texas produce good yields of cotton. Phaeozems in the temperate belt are sown with wheat, barley and vegetables alongside other crops. Wind and water erosion are serious hazards. Vast areas of Phaeozems are used for cattle rearing and fattening on improved pastures.

PLANOSOLS

Planosols are soils with a mostly light-coloured horizon that shows signs of periodic water stagnation and that abruptly overlies a dense, slowly permeable subsoil with significantly more clay. The name *Planosols* was coined in 1938 in the United States of America, where now most of them are included in the Great Groups of the *Albaqualfs*, *Albaquults* and *Argialbolls*. The name has been adopted in Brazil (*Planossolos*).

Summary description of Planosols

Connotation: Soils with a coarse-textured surface horizon abruptly over a dense and finer textured subsoil, typically in seasonally waterlogged flat lands; from Latin *planus*, flat.

Parent material: Mostly alluvial and colluvial deposits.

Environment: Seasonally or periodically wet, level (plateau) areas, mainly in subtropical and temperate, semi-arid and subhumid regions with light forest or grass vegetation.

Profile development: Geological stratification or pedogenesis (destruction and/or removal of clay), or both, has produced a relatively coarse-textured, light-coloured surface soil abruptly overlying a finer textured subsoil; impeded downward percolation of water causes temporarily *reducing conditions* with *stagnic* properties, at least close to the *abrupt textural difference*.

Regional distribution of Planosols

The world's major Planosol areas occur in subtropical and temperate regions with clear alternation of wet and dry seasons, e.g. in Latin America (southern Brazil, Paraguay and Argentina), Africa (Sahelian zone, eastern and southern Africa), the east of the United States of America, Southeast Asia (Bangladesh and Thailand) and Australia. Their total extent is estimated at some 130 million ha.

Management and use of Planosols

Natural Planosol areas support a sparse grass vegetation, often with scattered shrubs and trees that have shallow root systems and can cope with temporary waterlogging. Land use on Planosols is normally less intensive than that on most other soils under the same climate conditions. Vast areas of Planosols are used for extensive grazing. Wood production on Planosols is much lower compared with other soils under the same climate.

Planosols in the temperate zone are mainly used for pasture or they are planted with arable crops such as wheat and sugar beet. Yields are modest even on drained and deeply loosened soils. Root development on natural, unmodified Planosols is hindered severely by oxygen deficiency in the wet periods, the dense subsoil, and in places by toxic levels of Al in the rootzone. The low hydraulic conductivity of the dense subsurface horizon makes narrow drain spacing necessary. Surface modification such as ridge and furrow can lessen crop yield losses from waterlogging.

Planosols in Southeast Asia are widely planted with a single crop of paddy rice, produced on bunded fields that are inundated in the rainy season. Efforts to produce dryland crops on the same land during the dry season have met with little success; the soils seem better suited to a second crop of rice with supplementary irrigation. Fertilizers are needed for good yields. Paddy fields should be allowed to dry out at least once a year in order to prevent or minimize microelement deficiencies or toxicity associated with prolonged soil reduction. Some Planosols require application of more than just NPK fertilizers, and their low fertility level may prove difficult to correct. Where temperature permits paddy rice cultivation, this is probably superior to any other kind of land use.

Grasslands with supplementary irrigation in the dry season are a good land use in climates with long dry periods and short infrequent wet spells. Strongly developed Planosols with a very silty or sandy surface soil are perhaps best left untouched.

PLINTHOSOLS

Plinthosols are soils with plinthite, petroplinthite or pisoliths. Plinthite is a Fe-rich (in some cases also Mn-rich), humus-poor mixture of kaolinitic clay (and other products of strong weathering such as gibbsite) with quartz and other constituents. It usually changes irreversibly to a layer with hard concretions or nodules or to a hardpan on exposure to repeated wetting and drying. Petroplinthite is a continuous or fractured sheet of connected, strongly cemented to indurated concretions or nodules or concentrations in platy, polygonal or reticulate patterns. Pisoliths are discrete, strongly cemented to indurated concretions or nodules. Both petroplinthite and pisoliths develop from plinthite by hardening. Traditional names are *Groundwater Laterite Soils* and *Perched Water Laterite Soils*. Many of these soils are known as *Plintossolos* (Brazil), *Sols gris latéritiques* (France), *Petroferric Kandosols* (Australia) and *Plinthaquox*, *Plinthaqualfs*, *Plinthoxeralfs*, *Plinthustalfs*, *Plinthaquults*, *Plinthohumults*, *Plinthudults* and *Plinthustults* (United States of America).

Summary description of Plinthosols

Connotation: Soils with plinthite, petroplinthite or pisoliths; from Greek *plinthos*, brick.

Parent material: Plinthite is more common in weathering material from basic rock than in acidic rock weathering. In any case, it is crucial that sufficient Fe is present, originating either from the parent material itself or brought in from elsewhere by seepage water or ascending groundwater.

Environment: Formation of plinthite is associated with level to gently sloping areas with fluctuating groundwater or stagnating surface water. A widely held view is that plinthite is associated with rain forest whereas petroplinthic and pisolithic soils are more common in drier forests and savannahs.

Profile development: Strong weathering with subsequent segregation of Fe (and Mn) and the formation of plinthite at the depth of groundwater fluctuation or impeded surface water drainage. Hardening of plinthite to pisoliths or petroplinthite takes place upon repeated drying and wetting. This may occur during the intervals of recession of a seasonally fluctuating water table or after geological uplift of the terrain, topsoil erosion, lowering of the groundwater level, increasing drainage capacity, and/or climate change towards drier conditions. Hardening or induration requires a certain minimum concentration of iron oxides. Petroplinthite may break up into irregular aggregates or gravels, which may be transported to form colluvial or alluvial deposits which belong to a RSG other than Plinthosols.

Regional distribution of Plinthosols

The global extent of Plinthosols is estimated at some 60 million ha. Soft plinthite is most common in the wet tropics, notably in the eastern Amazon basin, the central Congo basin and parts of Southeast Asia. Extensive areas with pisoliths and petroplinthite occur in the Sudano-Sahelian zone, where petroplinthite forms hard caps on top of uplifted/exposed landscape elements. Similar soils occur in the southern African savannah, the South American cerrado region, on the Indian subcontinent and in drier parts of Southeast Asia and northern Australia.

Management and use of Plinthosols

Plinthosols present considerable management problems. Poor natural soil fertility caused by strong weathering, waterlogging in bottomlands and drought on Plinthosols with petroplinthite or pisoliths are serious limitations. Many Plinthosols outside of the wet tropics have continuous petroplinthite at shallow depth, which limits the rooting volume to the extent that arable farming is not possible; such land can at best be used for low-volume grazing. Soils with high contents of pisoliths (up to 80 percent) are still planted with food crops and tree crops (e.g. cocoa in West Africa and cashew in India), but the crops suffer from drought in the dry season.

Many soil and water conservation techniques are used to improve these soils for urban and peri-urban agriculture in West Africa.

Civil engineers have a different appreciation of plinthite and petroplinthite than do agronomists. To them, plinthite is a valuable material for making bricks, and massive petroplinthite is a stable surface for building or can be cut to building blocks. Gravels of broken petroplinthite can be used in foundations and as surfacing material on roads and airfields. In some instances, petroplinthite is a valuable ore of Fe, Al, Mn and/or Ti.

PODZOLS

Podzols have an illuvial horizon with accumulation of black organic matter and/or reddish Fe oxides. This illuvial horizon is typically overlain by an ash-grey eluvial horizon. Podzols occur in humid areas in the boreal and temperate zones and locally also in the tropics. The name *Podzol* is used in most national soil classification systems; other names for many of these soils are *Spodosols* (China and United States of America), *Espodossolos* (Brazil) and *Podosols* (Australia).

Summary description of Podzols

Connotation: Soils with an eluvial horizon that has the appearance of ash; from Russian *pod*, underneath, and *zola*, ash; it is directly underlain by the illuvial *spodic* horizon.

Parent material: Weathering materials of siliceous rock, including glacial till and alluvial and aeolian deposits of quartz sands. Podzols in the boreal zone mostly occur on hard siliceous rock.

Environment: Mainly in humid temperate and boreal regions of the Northern Hemisphere, in level to hilly land under heather and/or coniferous forest; in the humid tropics under light forest.

Profile development: Al, Fe and organic compounds migrate from the surface soil downwards with percolating rainwater. They precipitate in an illuvial *spodic* horizon. The overlying eluvial horizon remains bleached and consists in many Podzols of *albic* material. This eluvial horizon is usually overlain by a thin mineral horizon with a higher content of organic matter. The latter horizon is, at least in boreal and temperate regions, covered by an organic layer.

Regional distribution of Podzols

Podzols cover an estimated 485 million ha worldwide, mainly in the temperate and boreal regions of the Northern Hemisphere. They are extensive in Scandinavia, the northwest of the Russian Federation and Canada. Podzols are also present in humid temperate climates and in the humid tropics.

Tropical Podzols occur on less than 10 million ha, mainly in residual sandstone weathering in perhumid regions and in alluvial quartz sands, e.g. in uplifted coastal areas. The exact distribution of tropical Podzols is not known; important occurrences are found along the Rio Negro and in French Guiana, Guyana and Suriname in South America, in Southeast Asia (Kalimantan, Sumatra), in Papua New Guinea and in northern and eastern Australia. They seem to be less common in Africa.

Management and use of Podzols

Podzols in high latitude regions have unattractive climate conditions for most arable land uses. In temperate regions they are more frequently reclaimed for arable use. The low nutrient status, low level of available moisture and low pH make Podzols unattractive soils for arable farming. Aluminium toxicity and P deficiency are common problems. Deep ploughing (to improve the moisture storage capacity of the soil and/or to eliminate a dense illuviation horizon or hardpan), liming and fertilization are the main ameliorative measures taken. Trace elements may migrate with the metal–humus complexes. In the Western Cape region of South Africa, deeper rooted orchards and vineyards suffer fewer trace element deficiencies than do shallow-rooted vegetable crops.

Most Podzols are under forest or shrubs (heath). Tropical Podzols normally sustain a light forest that recovers only slowly after cutting or burning. Podzols are generally best used for extensive grazing or left under their natural vegetation.

REGOSOLS

Regosols are very weakly developed mineral soils in unconsolidated materials that do not have a *mollic* or *umbric* horizon, are not very thin or very rich in coarse fragments (*Leptosols*), not sandy (*Arenosols*), and not with *fluvic* materials (*Fluvisols*). Regosols are extensive in eroding lands and accumulation zones, particularly in arid and semi-arid areas and in mountainous terrain. Many Regosols correlate with soil taxa that are marked by incipient soil formation such as *Entisols* (United States of America), *Rudosols* (Australia), *Regosole* (Germany), *Sols peu évolués régosoliques d'érosion* or even *Sols minéraux bruts d'apport éolien ou volcanique* (France), *Pelozems* (Russia) and *Neossolos* (Brazil).

Summary description of Regosols

Connotation: Weakly developed soils in unconsolidated material; from Greek *rhegos*, blanket.

Parent material: unconsolidated, generally fine-grained material.

Environment: All climate zones without permafrost and at all elevations. Regosols are particularly common in arid areas (including the dry tropics) and in mountain regions.

Profile development: No diagnostic horizons. Profile development is minimal as a consequence of young age and/or slow soil formation, e.g. because of aridity.

Regional distribution of Regosols

Regosols cover an estimated 260 million ha worldwide, mainly in arid areas in the mid-west of the United States of America, northern Africa, the Near East and Australia. Some 50 million ha of Regosols occur in the dry tropics and another 36 million ha in mountain areas. The extent of most Regosol areas is limited; consequently Regosols are common inclusions in other map units on small-scale maps.

Management and use of Regosols

Regosols in desert areas have minimal agricultural significance. Regosols with rainfall of 500–1 000 mm/year need irrigation for satisfactory crop production. The low moisture holding capacity of these soils calls for frequent applications of irrigation water; sprinkler or trickle irrigation solves the problem but is rarely economic. Where rainfall exceeds 750 mm/year, the entire profile is raised to its water holding capacity early in the wet season; improvement of dry farming practices may then be a better investment than installation of costly irrigation facilities.

Many Regosols are used for extensive grazing. Regosols on colluvial deposits in the loess belt of Europe and North America are mostly cultivated; they are planted with small grains, sugar beet and fruit trees. Regosols in mountainous regions are delicate and best left under forest.

RETISOLS

Retisols have a clay illuviation horizon with an interfingering of bleached coarser-textured soil material into the illuviation horizon forming a net-like pattern. The interfingering bleached coarser-textured material is characterized by a partial removal of clay and free iron oxides. There may be also bleached coarser-textured material falling from the overlying horizon into cracks in the illuvial horizon. Many Retisols correlate with the *Podzoluvisols* of the Soil Map of the World (FAO–UNESCO, 1971–1981). In other systems they are called *Soddy-podzolic* or *Sodzolic* soils (Russia), *Fahlerden* (Germany), and *Glossaqualfs*, *Glossocryalfs* and *Glossudalfs* (United States of America). *Albeluvisols* of the former editions of WRB are included in the concept of Retisols.

Summary description of Retisols

Connotation: From Latin *rete*, net.

Parent material: Mostly unconsolidated glacial till, materials of lacustrine or fluvial origin and aeolian deposits (loess).

Environment: Flat to undulating plains under coniferous forest (including boreal taiga) or mixed forest. The climate is temperate to boreal with cold winters, short and cool summers, and an average annual precipitation sum of 500–1 000 mm. Precipitation is distributed evenly over the year, or in the continental part of the Retisol belt, has a peak in summer.

Profile development: A thin, dark surface horizon over a layer with coarser-textured *albic* material that interfingers as a net into an underlying brown *argic* or *natric* horizon. In some Retisols, the *albic* material forms tongues (*albeluvic glossae*) into the *argic* horizon. Temporarily *reducing conditions* with *stagnic* properties are common in boreal Retisols. Many *argic* horizons in Retisols are also *fragic* horizons.

Regional distribution of Retisols

Retisols cover an estimated 320 million ha in Europe, North Asia and Central Asia, with minor occurrences in North America. Retisols are concentrated in two regions, each having a particular set of climate conditions:

- the continental regions that had permafrost in the Pleistocene of northeastern Europe, northwestern Asia and southern Canada, which constitute by far the largest areas of Retisols;

- the loess and cover sand areas and old alluvial areas in moist temperate regions, such as France, central Belgium, the southeast of the Netherlands and the west of Germany.

Management and use of Retisols

The agricultural suitability of Retisols is limited because of their acidity, low nutrient levels, tillage and drainage problems, and for many Retisols because of the cool climate with its short growing season and severe frost during the long winter. The Retisols of the northern taiga zone are almost exclusively under forest; small areas are used as pasture or hay fields. In the southern taiga zone, less than 10 percent of the non-forested area is used for agricultural production. Livestock farming is the main agricultural land use on Retisols (dairy production and cattle rearing); arable cropping (cereals, potatoes, sugar beet and forage maize) plays a minor role.

In the Russian Federation, the share of arable farming increases in southern and western directions, especially on Retisols with higher base saturations in the subsoil. With careful tillage, liming and application of fertilizers, Retisols can produce 25–30 tonnes of potatoes per hectare, 2–5 tonnes of winter wheat or 5–10 tonnes of dry herbage.

SOLONCHAKS

Solonchaks have a high concentration of soluble salts at some time in the year. Solonchaks are largely confined to the arid and semi-arid climate zones and to coastal regions in all climates. Common international names are *Saline soils* and *Salt-affected soils*. In national soil classification systems many Solonchaks belong to *Halomorphic soils* (Russia), *Halosols* (China) and *Salids* (United States of America).

Summary description of Solonchaks

Connotation: Saline soils; from Russian *sol*, salt.

Parent material: Virtually any unconsolidated material, many of them containing salts.

Environment: Arid and semi-arid regions, notably in areas where ascending groundwater reaches the upper soil or where some surface water is present, with vegetation of grasses and/or halophytic herbs, and in inadequately managed irrigation areas. Solonchaks in coastal areas occur in all climates.

Profile development: From weakly to strongly weathered, many Solonchaks have *gleyic* properties at some depth. In low-lying areas with a shallow water table, salt accumulation is strongest at the soil surface (*external Solonchaks*). Solonchaks where ascending groundwater does not reach the topsoil have the greatest accumulation of salts at some depth below the soil surface (*internal Solonchaks*).

Regional distribution of Solonchaks

The total extent of Solonchaks in the world is estimated at about 260 million ha. Solonchaks are most extensive in the Northern Hemisphere, notably in the arid and semiarid parts of northern Africa, the Near East, the former Soviet Union and Central Asia; they are also widespread in Australia and the Americas.

Management and use of Solonchaks

Excessive accumulation of salts in soil affects plant growth in two ways:

- The salts aggravate drought stress because dissolved electrolytes create an osmotic potential that affects water uptake by plants. Before any water can be taken up from the soil, plants must compensate the combined forces of the matrix potential of the soil, i.e. the force with which the soil matrix retains water, and the osmotic potential. As a rule of thumb, the osmotic potential of a soil solution (in hectopascals) amounts to some 650 × EC (dS/m). The total potential that can be compensated by plants (known as the critical leaf water head) varies strongly between plant species. Plant species that stem from the humid tropics have a comparatively low critical leaf water head. For example, green peppers can compensate a total soil moisture potential (matrix plus osmotic forces) of only some 3 500 hPa whereas cotton, a crop that evolved in arid and semi-arid climates, survives some 25 000 hPa.

- The salts disturb the balance of ions in the soil solution because nutrients are proportionately less available. Antagonistic effects are known to exist, e.g. between Na and K, between Na and Ca, and between Mg and K. In higher concentrations, the salts may be directly toxic to plants. Very harmful in this respect are Na ions and chloride ions (they disturb N metabolism).

Farmers on Solonchaks adapt their cultivation methods. For example, plants on furrow-irrigated fields are not planted on the top of the ridges but at half height. This ensures that the roots benefit from the irrigation water while salt accumulation is strongest near the top of the ridge, away from the root systems. Strongly salt-affected soils have little agricultural value. They are used for extensive grazing of sheep, goats, camels and cattle or lie idle. Only after the salts have been flushed from the soil (which then ceases to be a Solonchak), good yields may be hoped for. Application of irrigation water must not only satisfy the needs of the crop, but excess water must be applied above the irrigation requirement in order to maintain a downward water flow in the soil and to flush excess salts from the root zone. Irrigation of crops in arid and semi-arid regions must be accompanied by drainage whereby drainage facilities should be designed to keep the groundwater table below the critical depth. Use of gypsum assists in maintaining hydraulic conductivity while salts are being flushed out with irrigation water.

SOLONETZ

Solonetz have a dense, strongly structured, clayey subsurface horizon that has a high proportion of adsorbed Na and in some cases also Mg ions. Solonetz that contain free soda (Na_2CO_3) are strongly alkaline (field pH > 8.5). Common international names are *Alkali soils* and *Sodic soils*. In national soil classification systems many Solonetz correlate with *Sodosols* (Australia), the *Solonetzic Order* (Canada) and *Solonetz* (Russia). In the United States of America, they belong to the *Natric* Great Groups of several Orders.

Summary description of Solonetz

Connotation: Soils with a high content of exchangeable Na, and in some cases also Mg ions; from Russian *sol*, salt.

Parent material: Unconsolidated materials, mostly fine-textured sediments.

Environment: Solonetz are normally associated with flat lands in a climate with hot, dry summers or with (former) coastal deposits that contain a high proportion of Na ions. Major concentrations of Solonetz are in flat or gently sloping grasslands with loam or clay (often derived from loess) in semi-arid temperate and subtropical regions.

Profile development: A clay-poorer surface soil over a clay-richer *natric* horizon that has mostly a columnar or prismatic structure. In well-developed Solonetz, the lower part of the eluviation horizon may consist of *albic* material. A *calcic* or *gypsic* horizon may be present below the *natric* horizon. Many Solonetz have a field pH of about 8.5, indicative of the presence of free sodium carbonate.

Regional distribution of Solonetz

Solonetz occur in areas with a semi-arid temperate continental climate (dry summers and an annual precipitation of not more than 400–500 mm), in particular in flat lands with impeded vertical and lateral drainage. They are also present in dry tropical and subtropical areas. Smaller occurrences are found on saline parent materials (e.g. marine clays or saline alluvial deposits). Worldwide, Solonetz cover some 135 million ha. Major Solonetz areas are found in Ukraine, the Russian Federation, Kazakhstan, Hungary, Bulgaria, Romania, China, the United States of America, Canada, South Africa, Argentina and Australia.

Management and use of Solonetz

The suitability of virgin Solonetz for agricultural use is dictated almost entirely by the depth and properties of the surface soil. A deep (> 25 cm) humus-rich surface soil is needed for successful arable crop production. However, most Solonetz have a much thinner surface horizon, and some may have lost the surface horizon altogether.

Solonetz amelioration has two basic elements:

- improvement of the porosity of the surface or subsurface soil;
- lowering of the ESP.

Most reclamation attempts start with incorporation of gypsum, or exceptionally, calcium chloride in the soil. Where lime or gypsum occur at shallow depth in the soil body, deep ploughing (mixing the carbonate- or gypsum-containing subsoil with the surface soil) may make expensive amendments superfluous. Traditional reclamation strategies start with the planting of a Na-resistant crop, e.g. Rhodes grass, to gradually improve the permeability of the soil. Once a functioning pore system is in place, Na ions are carefully leached from the soil with *good-quality* (Ca-rich) water (relatively pure water should be avoided because it exacerbates the dispersion problem).

An extreme reclamation method (developed in Armenia and applied successfully to Solonetz with a *calcic* or *petrocalcic* horizon in the Arax Valley) uses diluted sulfuric acid (a waste product of the metallurgical industry) to dissolve $CaCO_3$ contained in the soil. This brings Ca ions into the soil solution, which displace exchangeable Na. The practice improves soil aggregation and soil permeability. The resulting sodium sulfate (in the soil solution) is subsequently flushed out of the soil. In India, pyrite was applied to Solonetz to produce sulfuric acid, thus lowering extreme alkalinity and overcoming Fe deficiency. Ameliorated Solonetz can produce a fair crop foodgrain or forage. The majority of the world's Solonetz have never been reclaimed and are used for extensive grazing or lie idle.

STAGNOSOLS

Stagnosols are soils with perched water. They show periodically *reducing conditions* resulting in *stagnic* properties. Stagnosols have a mottled layer (with oxides predominantly inside the aggregates) with or without an overlying layer with *albic* material. Redox processes may also be caused by intruding liquids other than water (e.g. gasoline). A common name in many national soil classification systems for most Stagnosols is *Pseudogley*. In the United States of America many Stagnosols belong to *Aquic* Suborders and *Epiaquic* Great Groups of various Orders (*Aqualfs*, *Aquults*, *Aquents*, *Aquepts* and *Aquolls*).

Summary description of Stagnosols

Connotation: From Latin *stagnare*, to flood.

Parent material: A wide variety of unconsolidated materials including glacial till and loamy aeolian, alluvial and colluvial deposits, but also physically weathered silt stone.

Environment: Most common in flat or gently sloping land in cool temperate to subtropical regions with humid to perhumid climate conditions.

Profile development: Strong mottling due to redox processes caused by stagnating water; the topsoil can also be completely bleached (*albic* material).

Regional distribution of Stagnosols

Stagnosols cover 150–200 million ha worldwide; for the greater part in humid to perhumid temperate regions of West and Central Europe, North America, southeastern Australia, and Argentina, associated with Luvisols as well as silty to clayey Cambisols and Umbrisols. They also occur in humid to perhumid subtropical regions, associated with Acrisols and Planosols.

Management and use of Stagnosols

The agricultural suitability of Stagnosols is limited because of their oxygen deficiency resulting from stagnating water above a dense subsoil. In the wet season these soils are too wet, while they may be too dry for crop production in the dry season. However, in contrast to Gleysols, drainage with channels or pipes is in many cases insufficient due to the low hydraulic conductivity in the dense subsoil. Higher porosity may be achieved by deep loosening or deep ploughing. Drained Stagnosols can be fertile soils due to their moderate degree of nutrient leaching.

TECHNOSOLS

Technosols combine soils whose properties and pedogenesis are dominated by their technical origin. They contain a significant amount of *artefacts* (something in the soil recognizably made or strongly altered by humans or extracted from greater depths) or are sealed by *technic hard* material (hard material created by humans, having properties unlike natural rock) or contain a geomembrane. They include soils from wastes (landfills, sludge, cinders, mine spoils and ashes), pavements with their underlying unconsolidated materials, soils with geomembranes and constructed soils. Technosols are often referred to as *Urban* or *Mine* soils. They are recognized in the Russian soil classification system as *Technogenic superficial formations* and in the Australian soil classification, they are included in *Anthroposols*.

Summary description of Technosols

Connotation: Soils dominated or strongly influenced by human-made material; from Greek *technikos*, skilfully made.

Parent material: All kinds of materials made or exposed by human activity that otherwise would not occur at the Earth's surface; pedogenesis in these soils is affected strongly by materials and their organization.

Environment: Mostly in urban and industrial areas.

Profile development: Generally weak, although in old dumps (e.g. Roman rubble) evidence of natural pedogenesis can be observed, such as the formation of a *cambic* horizon. Lignite and fly ash deposits may exhibit over time *vitric* or *andic* properties. Original profile development may still be present in contaminated natural soils.

Regional distribution of Technosols

Technosols are found throughout the world where human activity has led to the construction of artificial soil, sealing of natural soil, or extraction of material normally not affected by surface processes. Thus, cities, roads, mines, refuse dumps, oil spills, coal fly ash deposits and the like are included in Technosols.

Management and use of Technosols

Technosols are strongly affected by the nature of the material or the human activity that placed it. They are more likely containing toxic substances than soils from other RSGs and have to be treated with care.

Many Technosols, in particular the ones in refuse dumps, are currently covered with a layer of natural soil material in order to permit revegetation. The soil remains a Technosol, provided that the requirement of having ≥ 20% (by volume, weighted average) *artefacts* in the upper 100 cm of the soil surface or to *continuous rock* or *technic hard* material or a cemented or indurated layer, whichever is shallower, is met.

UMBRISOLS

Umbrisols have a significant accumulation of organic matter in the mineral surface soil and a low base saturation somewhere within the first metre (in most cases in the mineral surface soil). Umbrisols are the logical counterpart of soils with a *chernic* or *mollic* horizon and a high base saturation throughout (Chernozems, Kastanozems and Phaeozems). Many of these soils are classified in other systems as several Great Groups of *Entisols* and *Inceptisols* (United States of America), *Sombric Brunisols* and *Humic Regosols* (France), *Mountain-meadow soils* (former USSR) and *Mucky-dark-humus* *soils* (Russia), *Brown podzolic soils* (e.g. Indonesia) and *Umbrisols* (Romania). In the Soil Map of the World (FAO–UNESCO, 1971–1981) most of them belong to *Humic Cambisols* and *Umbric Regosols*.

Summary description of Umbrisols

Connotation: Soils with dark topsoil; from Latin *umbra*, shade.

Parent material: Weathering material of siliceous rock or of strongly leached basic rock.

Environment: Humid climates; common in mountainous regions with little or no moisture deficit, in mostly cool to temperate areas but including tropical and subtropical mountains.

Profile development: Dark brown *umbric* (seldom: *mollic*) surface horizon, in some cases over a *cambic* subsurface horizon with low base saturation.

Regional distribution of Umbrisols

Umbrisols occur in cool to temperate humid regions, mostly mountainous and with little or no soil moisture deficit. They occupy about 100 million ha throughout the world. In South America, Umbrisols are common in the Andean ranges of Colombia, Ecuador, and to a lesser extent, in Venezuela, Bolivia and Peru. They also occur in Brazil, e.g. in the Serra do Mar. Umbrisols in North America are confined largely to the northwest Pacific seaboard. In Europe, Umbrisols occur along the northwest Atlantic seaboard, e.g. in Iceland, on the British Isles and in northwestern Portugal and Spain and in the Main Caucasus Ridge. In Asia, they are found in the mountain fringes of the Himalayas, notably in India, Nepal, China and Myanmar. Umbrisols occur at lower altitudes in Manipur (eastern India), in the Chin Hills (western Myanmar) and in Sumatra (Barisan range). In Oceania, Umbrisols are found in the mountain ranges of Papua New Guinea and southeastern Australia and in the eastern parts of South Island, New Zealand. They are also reported from mountainous regions in Africa like Lesotho and South Africa, e.g. the Drakensberg range.

Management and use of Umbrisols

Many Umbrisols are under a natural or near-natural vegetation cover. Umbrisols above the actual tree line in the Andean, Himalayan and Central Asian mountain ranges, or at lower altitudes in northern and western Europe where the former forest vegetation has been cleared largely, carry a vegetation of short grasses of low nutritional value. Coniferous forest predominates in Brazil (e.g. *Araucaria* spp.) and in the United States of America (mainly *Thuja*, *Tsuga* and *Pseudotsuga* spp.). Umbrisols in tropical mountain areas in South Asia and Oceania are under montane evergreen forest. In the mountains of southern Mexico, the vegetation varies from tropical semi-deciduous forest to much cooler montane cloud forest.

The predominance of sloping land and wet and cool climate conditions restricts utilization of many Umbrisols to extensive grazing. Management focuses on the introduction of improved grasses and correction of the soil pH by liming. Some Umbrisols are susceptible to erosion. The planting of perennial crops and bench or contour terracing offer possibilities for permanent agriculture on gentler slopes. Where conditions are suitable, cash crops may be grown, e.g. cereals and root crops in the United States of America, Europe and South America, or tea and cinchona in Southeast Asia (Indonesia). Highland coffee on Umbrisols demands high management inputs to meet its stringent nutrient requirements. In New Zealand, Umbrisols have been transformed into highly productive soils, used for intensive sheep and dairy farming and production of cash crops.

VERTISOLS

Vertisols are heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years. The name Vertisols (from Latin *vertere*, to turn) refers to the constant internal turnover (churning) of soil material. Common local names for Vertisols are *Black cotton soils* and *Regur* (India), *Black turf soils* (South Africa) or *Margalites* (Indonesia). In national soil classification systems they are called *Slitozems* or *Dark vertic soils* (Russia), *Vertosols* (Australia), *Vertissolos* (Brazil) and *Vertisols* (United States of America).

Summary description of Vertisols

Connotation: Churning, heavy clay soils; from Latin *vertere*, to turn.

Parent material: Sediments that contain a high proportion of swelling clays, or swelling clays produced by neoformation from rock weathering.

Environment: Depressions and level to undulating areas, mainly in tropical and subtropical, semi-arid to subhumid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or woodland.

Profile development: Alternate swelling and shrinking of expanding clays results in deep cracks in the dry season, and formation of slickensides and wedge-shaped structural elements in the subsurface soil. Shrink-swell behaviour may also cause gilgai microrelief to form, especially in drier climates.

Regional distribution of Vertisols

Vertisols cover 335 million ha worldwide. Most Vertisols occur in the semi-arid tropics with an average annual rainfall of 500–1 000 mm, but Vertisols are also found in the wet tropics, e.g. Trinidad (where annual rainfall amounts to 3 000 mm). The largest Vertisol areas are in Australia, India and South Sudan. They are also prominent in Ethiopia, China, southern United States of America (Texas), Uruguay, Paraguay, Argentina and South Africa. Vertisols are commonly associated with sediments that have a high content of smectitic clays or that produce such clays upon post-depositional weathering (e.g. in South Sudan and Australia) and on extensive basalt plateaus (e.g. in India and Ethiopia). Vertisols are often found in lower landscape positions such as dry lake bottoms, river basins, lower river terraces, and other lowlands that are periodically wet in their natural state. Small areas of Vertisols occur in southern European Russia and in Hungary.

Management and use of Vertisols

Large areas of Vertisols in the semi-arid tropics are still unused or are used only for extensive grazing, wood chopping, charcoal burning and the like. These soils have considerable agricultural potential, but adapted management is a precondition for sustained production. The comparatively good chemical fertility and their occurrence on extensive level plains where reclamation and mechanical cultivation can be envisaged are assets of Vertisols. Their physical soil characteristics, and notably their difficult water relations, cause management problems. Buildings and other structures on Vertisols are at risk and engineers have to take special precautions to avoid damage.

The agricultural uses of Vertisols range from very extensive (grazing, collection of fuelwood and charcoal burning) through smallholder post-rainy season crop production (millet, sorghum, cotton and chickpeas) to small-scale (rice) and large-scale irrigated agriculture (cotton, wheat, barley, sorghum, chickpeas, flax, noug [*Guzotia abessynica*] and sugar cane). Cotton is known to perform well on Vertisols, apparently because cotton has a vertical root system that is not damaged severely by cracking of the soil. Tree crops are generally less successful because tree roots find it difficult to establish themselves in the subsoil and are damaged as the soil shrinks and swells. Management practices for crop production should be directed primarily at water control in combination with conservation or improvement of soil fertility.

The physical properties and the soil moisture regime of Vertisols represent serious management constraints. The heavy soil texture and domination of expanding clay minerals result in a narrow soil moisture range between moisture stress and water excess. Tillage is hindered by stickiness when the soil is wet and hardness when it is dry. The susceptibility of Vertisols to waterlogging may be the single most important factor that reduces the actual growing period. Excess water in the rainy season must be stored for post-rainy season use (water harvesting) on Vertisols with very low infiltration rates.

A compensation for the shrink–swell characteristics is the phenomenon of self-mulching that is common on many Vertisols. Large clods produced by primary tillage break down with gradual drying into fine aggregates, which provide a passable seed bed with minimal effort. For the same reason, gully erosion on overgrazed Vertisols is seldom severe because gully walls soon assume a shallow angle of repose, which allows grass to become re-established more readily.

Annex 2

Summary of analytical procedures for soil characterization

This annex provides summaries of recommended analytical procedures to be used for soil characterization for the World Reference Base for Soil Resources. Full descriptions can be found in *Procedures for soil analysis* (Van Reeuwijk, 2002) and the USDA *Soil Survey Laboratory Methods Manual* (Burt, 2004).

1. SAMPLE PREPARATION

Samples are air-dried or alternatively oven-dried at a maximum of 40 °C. The fine earth fraction is obtained by sieving the dry sample with a 2mm sieve. Clods not passing through the sieve are crushed (not ground) and sieved again. Gravel, rock fragments, etc. not passing through the sieve are treated separately.

In special cases where air-drying causes unacceptable irreversible changes in certain soil properties (e.g. in peat and soils with *andic* properties), samples are kept and treated in the field-moist state.

2. MOISTURE CONTENT

Calculation of results of soil analyses is done on the basis of *oven-dry* (105 °C) soil mass.

3. PARTICLE-SIZE ANALYSIS

The mineral part of the soil is separated into various size fractions and the proportion of these fractions is determined. The determination comprises all material, i.e. including gravel and coarser material, but the procedure itself is applied to the fine earth (< 2 mm) only.

The pre-treatment of the sample is aimed at complete dispersion of the primary particles. Therefore, cementing materials (usually of secondary origin) such as organic matter and calcium carbonate may have to be removed. In some cases, de-ferration also needs to be applied. However, depending on the aim of study, it may be fundamentally wrong to remove cementing materials. Thus, all pre-treatments are considered optional. However, for soil characterization purposes, removal of organic matter by H_2O_2 and of carbonates by HCl is routinely carried out. After this pre-treatment, the sample is shaken with a dispersing agent and sand is separated from clay and silt with a 63µm sieve. The sand is fractionated by dry sieving; the clay and silt fractions are determined by the pipette method or alternatively, by the hydrometer method.

4. WATER-DISPERSIBLE CLAY

This is the clay content found when the sample is dispersed with water without any pre-treatment to remove cementing compounds and without use of a dispersing agent. The proportion of natural clay to total clay can be used as a structure stability indicator.

5. SOIL WATER RETENTION

The water content is determined of soil samples that have been equilibrated with water at various suction (tension) values. For low suction values, undisturbed core samples are equilibrated on a silt and kaolin bath; for high suction values, disturbed samples are equilibrated in pressure plate extractors. The bulk density is calculated from the core sample mass.

6. BULK DENSITY

Soil bulk density is the mass per unit volume of soil. As bulk density changes with water content, the water status of the sample must be specified.

Two different procedures can be used:

- *Undisturbed core samples*. A metal cylinder of known volume is pressed into the soil. The moist sample mass is recorded. This may be the field-moist state or the state after equilibrating the sample at a specified water tension. The sample is then oven-dried and weighed again. The bulk density is the ratio of dry mass to volume at the determined water content and/or the specified water tension.

- *Coated clods.* Field-occurring clods are coated with plastic lacquer (e.g. Saran dissolved in methyl ethyl ketone) to allow determination of underwater mass. This gives the volume of the clod. The moist sample mass is recorded. This may be the field-moist state or the state after equilibrating the clod at specified water suction. The sample is then oven-dried and weighed again. The bulk density is the ratio of dry mass to volume at the specified water suction.

***Note*:** The determination of bulk density is very sensitive to errors, particularly caused by non-representativeness of the samples (stones, cracks, roots, etc.). Therefore, determinations should always be made in triplicate.

7. COEFFICIENT OF LINEAR EXTENSIBILITY (COLE)

The COLE gives an indication of the reversible shrink–swell capacity of a soil. It is calculated from the *dry* bulk density and the bulk density at 33 kPa water suction. The COLE value is expressed in centimetres per centimetre or as a percentage value.

8. pH

The pH of the soil is potentiometrically measured in the supernatant suspension of a soil:liquid mixture. If not stated otherwise, soil:liquid are in a ratio of 1:5 (volume:volume) (according to ISO standards). The liquid is either distilled water (pH_{water}) or a 1 *M* KCl solution (pH_{KCl}). However, in some definitions, a 1:1 soil:water ratio is used.

9. ORGANIC CARBON

The Walkley–Black procedure is followed. This involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulfuric acid at about 125 °C. The residual dichromate is titrated against ferrous sulfate. To compensate for incomplete destruction, an empirical correction factor of 1.3 is applied in the calculation of the result.

Note**:** Other procedures, including carbon analysers (e. g. dry combustion) may also be used. In these cases a qualitative test for carbonates on effervescence with HCl is recommended, and if applicable, a correction for inorganic C (see Carbonate below) is required.

10. CARBONATES

The *rapid titration method* by Piper (also called *acid neutralization method*) is used. The sample is treated with dilute HCl and the residual acid is titrated. The results are referred to as *calcium carbonate equivalent* as the dissolution is not selective for calcite and also other carbonates such as dolomite are dissolved to some extent.

Note**:** Other procedures such as the Scheibler volumetric method or the Bernard calcimeter may also be used.

11. GYPSUM

Gypsum is dissolved by shaking the sample with water. It is then selectively precipitated from the extract by adding acetone. This precipitate is re-dissolved in water and the Ca concentration is determined as a measure for gypsum.

12. CATION EXCHANGE CAPACITY (CEC) AND EXCHANGEABLE BASES

The ammonium acetate pH 7 method is used. The sample is percolated with ammonium acetate (pH 7) and the bases are measured in the percolate. The sample is subsequently percolated with sodium acetate (pH 7), the excess salt is then removed and the adsorbed Na exchanged by percolation with ammonium acetate (pH 7). The Na in this percolate is a measure for the CEC.

Alternatively, after percolation with ammonium acetate, the sample can be washed free of excess salt, the whole sample distilled and the evolved ammonia determined.

Percolation in tubes may also be replaced by shaking in flasks. Each extraction must be repeated three times and the three extracts should be combined for analysis.

Note 1**:** Other procedures for CEC may be used provided the determination is done at pH 7.

Note 2**:** In special cases where CEC is not a diagnostic criterion, e.g. saline and alkaline soils, the CEC may be determined at pH 8.2.

Note 3**:** The base saturation of saline, calcareous and gypseous soils can be considered to be 100%.

Note 4**:** Where low-activity clays are involved, the CEC of the organic matter has to be deducted. This can be done by the graphical method (FAO, 1966), or by analysing the CEC of the organic matter or the mineral colloids separately.

13. EXCHANGE ACIDITY AND EXCHANGEABLE ALUMINIUM

Exchange acidity (H + Al) and exchangeable Al are released upon exchange by an unbuffered 1 *M* KCl solution. Exchange acidity may also be designated *actual* acidity (as opposed to *potential* or *extractable acidity*).

14. EXTRACTABLE IRON, ALUMINIUM, MANGANESE AND SILICON

These analyses comprise:

- Fe_{dith}, Al_{dith}, Mn_{dith}: *Free* Fe, Al and Mn compounds in the soil extracted by a dithionite-citrate-bicarbonate solution. (Both the Mehra and Jackson and the Holmgren procedures may be used.)

- Fe_{ox}, Al_{ox}, Si_{ox}: *Active*, *short-range-order* or *amorphous* Fe, Al and Si compounds extracted by an acid ammonium oxalate solution (pH 3). (Blakemore *et al*., 1987.)

- Fe_{py}, Al_{py}: *Organically bound* Fe and Al extracted by a pyrophosphate solution.

15. SALINITY

Attributes associated with salinity in soils are determined in the *saturation extract*. The attributes include: pH, electrical conductivity (EC_e), sodium adsorption ratio (SAR) and the cations and anions of the dissolved salts. These include Ca, Mg, Na, K, carbonate and bicarbonate, chloride, nitrate and sulfate. The SAR and the exchangeable sodium percentage (ESP) may be estimated from the concentrations of the dissolved cations.

16. PHOSPHATE AND PHOSPHATE RETENTION

These analyses comprise:

- Olsen method: Extraction with a 0.5 *M* $NaHCO_3$ solution at pH 8.5 (Olsen *et al*. 1954).

- Citric acid method: Extraction with a 1% citric acid solution (Blanck, 1931; van Reeuwijk, 2002).

- Mehlich-1 method: Extraction with a solution of 0.05 M HCl and 0.025 M H_2SO_4 (Mehlich, 1953).

- For phosphate retention, the *Blakemore* procedure is used. The sample is equilibrated with a phosphate solution at pH 4.6 and the proportion of phosphate withdrawn from solution is determined (Blakemore *et al*., 1987).

17. OPTICAL DENSITY OF OXALATE EXTRACT (ODOE)

The sample is percolated or shaken with an acid ammonium oxalate solution (pH 3). The optical density of the extract is measured at 430 nm wavelength.

18. MELANIC INDEX

The sample is shaken with a 0.5 *M* NaOH solution and the absorbance of the extract is measured at 450 and 520 nm, respectively. The *melanic index* is obtained by dividing the absorbance at 450 nm by the absorbance at 520 nm.

19. MINERALOGICAL ANALYSIS OF THE SAND FRACTION

After removal of cementing and coating materials, the sand is separated from the clay and silt by wet sieving. From the sand, the fraction 63–420 µm is separated by dry sieving. This fraction is divided into a *heavy* fraction and a *light* fraction with the aid of a high-density liquid: a solution of sodium polytungstate[1] with a specific density of 2.85 kg dm^{-3}. Of the *heavy fraction*, a microscopic slide is made; the *light fraction* is stained selectively for microscopic identification of feldspars and quartz.

Volcanic glass can usually be recognized as isotropic grains with vesicles.

20. X-RAY DIFFRACTOMETRY

The clay fraction is separated from the fine earth and deposited in an oriented fashion on glass slides or porous ceramic plates to be analysed on an Xray diffractometer. Unoriented powder specimens of clay and other fractions are analysed on the same apparatus or with a Guinier Xray camera (photographs).

21. SULFIDES

Reduced inorganic S is converted to H_2S by a hot acidic $CrCl_2$ solution. The evolved H_2S is trapped quantitatively in a Zn acetate solution as solid ZnS. The ZnS is then treated with HCl to release H_2S into solution, which is quickly titrated with I_2 solution to the blue-coloured end point indicated by the reaction of I_2 with starch (Sullivan *et al*., 2000). Caution: Toxic residues have to be managed carefully.

[1] Bromoform can also be used as high density liquid but its use is discouraged because of its highly toxic vapour.

Annex 3

Recommended codes for the Reference Soil Groups, qualifiers and specifiers

Overview of Key to Reference Soil Groups							
Acrisol	AC	Cryosol	CR	Leptosol	LP	Regosol	RG
Alisol	AL	Durisol	DU	Lixisol	LX	Retisol	RT
Andosol	AN	Ferralsol	FR	Luvisol	LV	Solonchak	SC
Anthrosol	AT	Fluvisol	FL	Nitisol	NT	Solonetz	SN
Arenosol	AR	Gleysol	GL	Phaeozem	PH	Stagnosol	ST
Calcisol	CL	Gypsisol	GY	Planosol	PL	Technosol	TC
Cambisol	CM	Histosol	HS	Plinthosol	PT	Umbrisol	UM
Chernozem	CH	Kastanozem	KS	Podzol	PZ	Vertisol	VR

Qualifiers							
Abruptic	ap	Argisodic	as	Cutanic	ct	Fragic	fg
Aceric	ae	Aric	ai	Densic	dn	Fulvic	fu
Acric	ac	Aridic	ad	Differentic	df	Garbic	ga
Acroxic	ao	Arzic	az	Dolomitic	do	Gelic	ge
Aeolic	ay	Brunic	br	Drainic	dr	Gelistagnic	gt
Akrofluvic	kf	Calcaric	ca	Duric	du	Geoabruptic	go
Akromineralic	km	Calcic	cc	Dystric	dy	Geric	gr
Akroskeletic	kk	Calcifractc	cf	Ekranic	ek	Gibbsic	gi
Albic	ab	Cambic	cm	Entic	et	Gilgaic	gg
Alcalic	ax	Capillaric	cp	Escalic	ec	Glacic	gc
Alic	al	Carbic	cb	Eutric	eu	Gleyic	gl
Aluandic	aa	Carbonatic	cn	Eutrosilic	es	Glossic	gs
Andic	an	Carbonic	cx	Evapocrustic	ev	Greyzemic	gz
Anthraquic	aq	Chernic	ch	Ferralic	fl	Grumic	gm
Anthric	ak	Chloridic	cl	Ferric	fr	Gypsic	gy
Anthromollic	am	Chromic	cr	Ferritic	fe	Gypsifractic	gf
Anthrotoxic	at	Clayic	ce	Fibric	fi	Gypsiric	gp
Anthroumbric	aw	Clayinovic	cj	Floatic	ft	Haplic	ha
Archaic	ah	Colluvic	co	Fluvic	fv	Hemic	hm
Arenic	ar	Columnic	cu	Folic	fo	Histic	hi
Areninovic	aj	Cryic	cy	Fractic	fc	Hortic	ht

Qualifiers							
Humic	hu	Lignic	lg	Ortsteinic	os	Reductic	rd
Hydragric	hg	Limnic	lm	Oxyaquic	oa	Reductigleyic	ry
Hydric	hy	Linic	lc	Oxygleyic	oy	Relictigleyic	rl
Hydrophobic	hf	Lithic	li	Pachic	ph	Relictistagnic	rw
Hyperalic	jl	Lixic	lx	Pellic	pe	Relictiturbic	rb
Hyperartefactic	ja	Loamic	lo	Petric	pt	Relocatic	rc
Hypercalcic	jc	Loaminovic	lj	Petrocalcic	pc	Rendzic	rz
Hyperduric	ju	Luvic	lv	Petroduric	pd	Retic	rt
Hyperdystric	jd	Magnesic	mg	Petrogleyic	py	Rheic	rh
Hypereutric	je	Manganiferric	mf	Petrogypsic	pg	Rhodic	ro
Hyperferritic	jf	Mawic	mw	Petroplinthic	pp	Rockic	rk
Hypergypsic	jg	Mazic	mz	Petrosalic	ps	Rubic	ru
Hyperhumic	jh	Melanic	ml	Phytotoxic	yx	Rustic	rs
Hyperhydragric	jy	Mesotrophic	ms	Pisoplinthic	px	Salic	sz
Hypermagnesic	jm	Mineralic	mi	Placic	pi	Sapric	sa
Hypernatric	jn	Mollic	mo	Plaggic	pa	Sideralic	se
Hyperorganic	jo	Murshic	mh	Plinthic	pl	Silandic	sn
Hypersalic	jz	Muusic	mu	Plinthofractic	pf	Siltic	sl
Hypersideralic	jr	Natric	na	Posic	po	Siltinovic	sj
Hyperskeletic	jk	Nechic	ne	Pretic	pk	Skeletic	sk
Hyperspodic	jp	Neocambic	nc	Profondic	pn	Sodic	so
Hypersulfidic	js	Nitic	ni	Profundihumic	dh	Sombric	sb
Hypertechnic	jt	Novic	nv	Protic	pr	Someric	si
Hyperthionic	ji	Nudiargic	ng	Protoandic	qa	Somerimollic	sm
Hypocalcic	wc	Nudilithic	nt	Protoargic	qg	Somerirendzic	sr
Hypogypsic	wg	Nudinatric	nn	Protoaridic	qd	Someriumbric	sw
Hyposulfidic	ws	Nudipetric	np	Protocalcic	qc	Spodic	sd
Hypothionic	wi	Nudiyermic	ny	Protosalic	qz	Spolic	sp
Immissic	im	Ochric	oh	Protosodic	qs	Stagnic	st
Inclinic	ic	Oligoeutric	ol	Protospodic	qp	Subaquatic	sq
Infraandic	ia	Ombric	om	Protostagnic	qw	Sulfatic	su
Infraspodic	is	Organotransportic	ot	Prototechnic	qt	Sulfidic	sf
Irragric	ir	Ornithic	oc	Prototephric	qf	Takyric	ty
Isolatic	il	Orthodystric	od	Protovertic	qv	Technic	te
Lamellic	ll	Orthoeutric	oe	Puffic	pu	Technoleptic	tl
Lapiadic	ld	Orthofluvic	of	Radiotoxic	rx	Technolithic	tt
Laxic	la	Orthomineralic	oi	Raptic	rp	Technoskeletic	tk
Leptic	le	Orthoskeletic	ok	Reductaquic	ra	Tephric	tf

Qualifiers							
Terric	tr	Tonguimollic	tm	Umbric	um	Vetic	vt
Thionic	ti	Tonguiumbric	tw	Urbic	ub	Vitric	vi
Thixotropic	tp	Totilamellic	ta	Uterquic	uq	Xanthic	xa
Tidalic	td	Toxic	tx	Vermic	vm	Yermic	ye
Tonguic	to	Transportic	tn	Vertic	vr	Zootoxic	zx
Tonguichernic	tc	Turbic	tu				

Specifiers							
Amphi	..m	Endo	..n	Kato	..k	Supra	..s
Ano	..a	Epi	..p	Panto	..e	Thapto	..b
Bathy	..d						

Rules for the use of the codes for naming soils

At the first level of classification, the code of the RSG stands alone.

At the second level, the code starts with the RSG,

followed by a '-',

followed by the principal qualifiers according to the list from top to bottom, with a '.' between them,

followed by a '-',

followed by the supplementary qualifiers in alphabetical order of the qualifier names (not in alphabetical order of their codes), with a '.' between them,

followed by a '-',

followed, if applicable, by qualifiers with the Bathy- or Thapto- specifier, with a '.' between them,

followed by a '-',

followed, if applicable, by qualifiers that are not in the list for the particular RSG.

Subqualifiers (qualifiers combined with specifiers) are placed in the order of the quali-fiers as if they were used without the specifier. Exceptions: If used with a principal qualifier, the Proto-, Bathy- and Thapto- subqualifiers must shift to the supplementary qualifiers.

If one group of qualifiers is empty, the '-' is still included, if one of the following groups is not empty.

The resulting scheme is as follows:

RSG{-}[PQ1[.PQ2]etc]{-}[SQ1[.SQ2]etc]{-}[BTQ1[.BTQ2]etc][-NQ1[.NQ2]etc]

With: PQ = principal qualifier, with or without added specifiers, SQ = supplementary qualifier, with or without added specifiers, BTQ = Bathy-/Thapto- subqualifier, NQ = qualifier not listed for the particular RSG; etc = further qualifiers can be added in the same way if necessary; elements in [] are listed if they apply; elements in {} are necessary if elements follow.

Examples of the use of the codes for naming soils

Albic Stagnic Luvisol (Endoclayic, Cutanic, Differentic, Episiltic):
LV-st.ab-cen.ct.df.slp

Dystric Hemic Folic Endorockic Histosol:
HS-rkn.fo.hm.dy

Haplic Ferralsol (Dystric, Loamic, Vetic, Bathypetroplinthic):
FR-ha-dy.lo.vt-ppd

Calcaric Skeletic Pantofluvic Fluvisol (Pantoarenic, Aridic):
FL-fve.sk.ca-are.ad

Dystric Umbric Aluandic Andosol (Siltic, Thaptofolic):
AN-aa.um.dy-sl-fob

Isolatic Technosol (Supraarenic, Supracalcaric):
TC-il-ars.cas

Dystric Katoalbic Arenosol (Bathyhyperspodic):
AR-abk.dy--jpd

Rules for the use of the codes for creating map legends

At the first scale level, the code of the RSG stands alone.

At the second, third and fourth scale level, the code starts with the RSG,

followed by a '-',

followed by the principal qualifiers (number according to the scale level) according to the list from top to bottom, with a '.' between them.

If qualifiers are added optionally,

a '-' is added,

followed by the optionally added qualifiers, with a '.' between them (the principal qualifiers are placed first, and of them, the first applicable qualifier is placed first, and the sequence of any supplementary qualifiers added is decided by the soil scientist who makes the map).

If according to the scale level no principal qualifier has to be added, the '-' is still included, if any qualifier is added optionally.

If codominant or associated soils are indicated, the words 'dominant:', 'codominant:' and 'associated:' are written before the code of the soil.

The resulting scheme is as follows:

RSG{-}[PQ1[.PQ2[.PQ3]]][-OQ1[.OQ2]etc]

With: PQ = principal qualifier, OQ = optional qualifier; etc = further qualifiers can be added in the same way if necessary; elements in [] are listed if they apply; elements in {} are necessary if elements follow.

Examples of the use of the codes for creating map legends

Geric Umbric Xanthic Plinthic Ferralsols (Clayic, Dystric):

first scale level: FR

second scale level: FR-pl

third scale level: FR-pl.xa

fourth scale level: FR-pl-xa-um

If qualifiers are added optionally: examples:

first scale level: FR--pl

second scale level: FR-pl-xa.um.dy

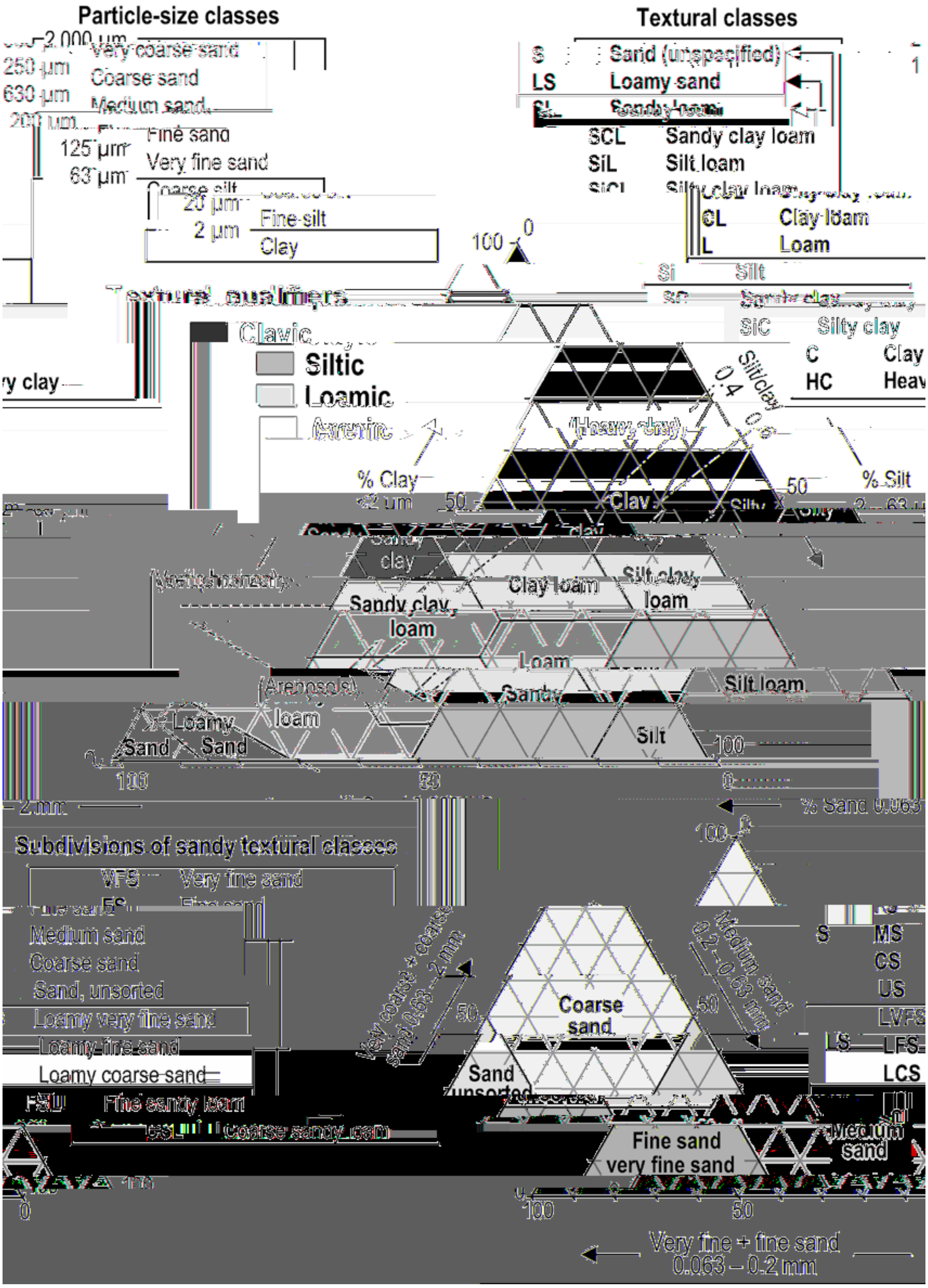
third scale level: FR-pl.xa-um.dy

fourth scale level: FR-pl.xa.um-gr.dy.ce

Annex 4

Soil particle-size and texture classes

Relation of constituents of fine earth by size, defining textural classes and sand subclasses



Source: Adapted from FAO (2006): Guidelines for Soil Description

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WORLD SOIL RESOURCES REPORTS

World reference base for soil resources 2014

International soil classification system for naming soils and creating legends for soil maps

Update 2015

This publication is a revised and updated version of World Soil Resources Reports No. 84 and 103 and presents the international soil classification system. Every soil in the world can be allocated to one of the 32 Reference Soil Groups as defined in this document, and can further be characterized by a set of qualifiers. The resulting soil name provides information on soil genesis, soil ecological function and soil properties relevant for land use and management. The same system, refined slightly, may be used to name the units of soil map legends, thereby providing comprehensive spatial information. By accommodating national soil classification systems, the World Reference Base facilitates the worldwide correlation of soil information.

GLOBAL SOIL PARTNERSHIP

International Union of Soil Sciences

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