THE **AUSTRALIAN SOIL CLASSIFICATION**

THIRD EDITION

R. F. Isbell
and the National Committee on Soil and Terrain

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The authors

Raymond Frederick Isbell (1928–2001)

Ray Isbell had a distinguished international career as a soil scientist, specialising in soil characterisation, distribution, genesis and classification. He was recognised overseas and at home as the Australian pedologist with the widest experience of Australian and world soils. He travelled extensively in the tropics and worked on comparative pedology, particularly in Africa and South America.

Ray graduated as a geologist and commenced his soil science career with the Queensland Bureau of Investigation where he was involved in soil surveys and soil assessment for proposed irrigation areas and other land development releases in southern and central Queensland. He joined CSIRO in 1958 and embarked upon a study of lands in eastern Australia dominated by brigalow (*Acacia harpophylla*). This sparked Ray's interest in cracking clay soils and led to an input into the development of the Ug classification in the Factual Key (Northcote 1979).

Ray was responsible for the compilation of the Atlas of Australian Soils for substantial parts of Queensland. These 1:250 000 compilation sheets have been widely used for extension and research purposes, and for large areas of Queensland remain as the best soil information available.

Ray was involved in the preparation of the CSIRO Division of Soils book *Soils: An Australian Viewpoint*, both as a contributor and in an editorial capacity. This was a benchmark publication in soil science, bringing together the accumulated knowledge of Australian soil science over the previous 50 years. He was also involved in the preparation of the first edition of the *Australian Soil and Land Survey Field Handbook*, which established standardised methods for describing soil and land attributes in Australia. He was also co-editor and contributor to a book entitled *Australian Soils: The Human Impact*, which looked at the management of Australian soils over the last 40 000 years of human habitation. During the 1980s Ray was a member of several international committees set up by the United States Department of Agriculture to advise on improvements to *Soil Taxonomy* in relation to oxic soils and cracking clays.

From the mid to late 1980s, Ray's major research activity was development of the *Australian Soil Classification*. The decision to develop a new classification system was taken after a survey of members of the Australian Society of Soil Science and considerable discussion on alternative approaches. While it was to be the task of a Technical Committee under the auspices of the Standing

Committee on Soil Conservation, Ray inherited sole responsibility for development of the new system with the support of many within the Australian soil science community.

Development of the *Australian Soil Classification* was gruelling and technically demanding but Ray was a good listener, and he communicated regularly with pedologists not only in Australia and New Zealand but also across the world in his quest to devise the system. He built networks and established a rapport with a younger generation of pedologists as he tested the classification during its three approximations and after the official publication of the first edition in 1996. Always ready to share his knowledge, he inspired colleagues during his field visits to assess the many classification challenges presented. One of his golden rules was to describe and interpret the *soil profile* accurately so that it could be classified with a minimum of fuss. The result was a unique personal understanding of Australian soils and this knowledge, combined with his great diplomacy and excellent judgement, has produced the best and, to date, most widely accepted national classification of Australian soils.

In retirement, but supported by CSIRO, Ray worked tirelessly to share his knowledge of Australian soils and landscapes. He continued to publish and maintained an active dialogue with soil scientists around the world. He continued to refine the Classification and, although clearly ill and almost totally dependent on his friends for personal help and transport, he actively contributed to the Australian Collaborative Land Evaluation Program. During this time he developed close links with the CSIRO Land & Water pedology group in Canberra, became a valued mentor, teacher and friend, and contributed significantly to the landmark book *Australian Soils and Landscapes* (McKenzie *et al*. 2004). After a long illness, Ray Isbell died in December 2001 at the age of 73.

National Committee on Soil and Terrain (NCST)

The NCST is the peak national committee overseeing national standards in soil characterisation and description. The NCST, through its subcommittee the Australian Soil Classification Working Group, is responsible for revisions of the *Australian Soil Classification*. The Australian Soil Classification Working Group comprises Bernie Powell (Chair, QLD), Noel Schoknecht (WA), Ted Griffin (WA), Ben Harms (QLD), Mark Imhof (VIC), James Hall (SA), Brian Lynch (NT), Mark Thomas (CSIRO), David Rees (VIC), David Morand (NSW) and Rob Moreton (TAS).

More information about the history of the *Australian Soil Classification* is provided in Appendix 6.

Contents

Acknowledgements

A large number of people over a long period of time greatly assisted in the development of the *Australian Soil Classification*. A particular debt is owed to all State and Territory organisations and their soil surveyors who made possible numerous and informative field trips with Ray Isbell, and who contributed constructive comments on the various drafts of the publication and made available a great deal of unpublished data. The West Australian, Victorian, New South Wales and Riverina branches of the Australian Society of Soil Science organised trips and discussion groups to test earlier versions of the scheme.

Special tribute is paid to Ron McDonald, formerly of the Queensland Department of Primary Industries. From the inception of the project until his untimely death in 1989, Ron was a never-failing source of help and inspiration. It was a matter of great regret for Ray that Ron did not live to see many of his ideas and enthusiasm come to fruition. Bernie Powell, then a member of the same Department, ably carried on Ron's role and contributed many useful ideas that greatly improved the Classification.

Several people deserve special mention. George Hubble and Cliff Thompson, previously with CSIRO Division of Soils in Brisbane, provided the basis for the classification of the Organosols and Podosols respectively. David Maschmedt, James Hall and Bruce Billing, then members of Primary Industries, South Australia, are thanked for their considerable help with the Calcarosols and other soils. Ray's long-time colleague in CSIRO, Graham Murtha, was an invaluable sounding board for Ray and was a constructive critic at all times. He was largely responsible for suggesting and organising the coding system, assisting with database activities, and helping to establish computer files and search programs. Warwick McDonald and Courtney Frape (CSIRO) provided database support and assistance with format and coding. Some ideas on layout were also obtained from the New Zealand Soil Classification (Hewitt 1992). The original manuscript was produced with assistance from Wendy Strauch and Helen Rodd (CSIRO, Townsville). Approximately 20 referees read all or parts of the original publication and provided many helpful suggestions to improve the text. More information about the early history of the *Australian Soil Classification* and contributors to the earlier editions is provided in Appendix 6.

With the third edition, the Working Group is indebted to several people who assisted in its preparation. In particular, working group member Noel Schoknecht (WA) provided the detailed submission and many working drafts for an Arenosols Order. Ted Griffin (WA), Ben Harms (QLD), David Morand (NSW), David Maschmedt (SA) and Brian Lynch (NT) organised database testing and Peter Wilson and Linda Gregory (CSIRO) assisted with the preparation of distribution maps. Stephen Cattle (University of Sydney) and Andrew Biggs (QLD) willingly provided assistance with ensuring consistency of terminology with the *Australian Soil and Land Survey Field Handbook* (NCST 2009).

Professor Rob Fitzpatrick (University of Adelaide) contributed data and conceptual advice on mineral sands and Rob Moreton (TAS) provided supporting information on shallow peats.

CSIRO is thanked for supporting the development of the *Australian Soil Classification* over a long period.

Soil Science Australia is thanked for its support, including hosting the web version of this edition.

Bernie Powell and Noel Schoknecht, assisted by Ben Harms, edited the new edition. Noel Schoknecht prepared the text and website for publication.

Preface to the third edition

With the first edition of the *Australian Soil Classification*, the availability of classified *soil profiles* was skewed towards Queensland (46.6%) due to the limited accessibility of good quality data elsewhere. That situation has dramatically changed, with a greater proportion of quality sites now available from most other states or territories. The period 1996 to 2018 saw a 10-fold increase (from 14 054 to 143 112) in classified profiles (Table 1), and the number of sites available with an Australian Soil Classification is increasing each year. The available dataset is now far more representative of Australian soils and their properties, providing good evidence for the significant changes in this new edition of the *Australian Soil Classification*.

The revised, second and third editions of the *Australian Soil Classification* have been the result of the ongoing data collection and improved understanding of gaps in soil knowledge. The Working Group on Land Resource Assessment prepared the revised edition, published in 2002. To manage the ongoing updating of the classification, the National Committee on Soil and Terrain (NCST) established the Australian Soil Classification Working Group in 2013 to assess proposals for change and make recommendations to the NCST. Following recommendations by the Working Group, in 2016 the NCST

Table 1. Number (percentage) of sites classified to at least Order in 1996 and 2018

State/territory	Area %	1996[1]	2018[2]
ACT	<1	42 (0.3%)	731 (0.5%)
NSW	10.4	2250 (16%)	21 326 (14.9%)
VIC	3	1142 (8.1%)	7070 (4.9%)[3]
QLD	22.5	6550 (46.6%)	45 122 (31.5%)
SA	12.7	1524 (10.9%)	19 645 (13.7%)
WA	33.0	1327 (9.4%)	14 721 (10.3%)
TAS	0.9	488 (3.5%)	4890 (3.4%)
NT	17.5	734 (5.2%)	29 607 (20.7%)
AUSTRALIA	100	14 057 (100%)	143 112 (100%)

Sources:
[1] *Australian Soil Classification*, first edition (Ray Isbell 1996)
[2] National soil site data collation for the Australian Soil Landscape Grid 2018 (Peter Wilson and Ross Searle, CSIRO)
[3] Victorian soils database (Mark Imhof, Agriculture Victoria, 2019)

released a second edition to accommodate new knowledge and understanding of soils containing *sulfidic materials*. Included in these changes was the introduction of *subtidal* and *subaqueous soils*. Soils with abundant ironstone gravels were also accommodated by a Sesqui-Nodular Suborder in Tenosols.

The modifications incorporated into this third edition are the second approved recommendations from the Working Group. The most prominent modifications relate to definitions and expanding of the key to accommodate an Arenosol Order for deep sands, as proposed by Noel Schoknecht (WA). Deep sands were previously classified as Tenosols, Rudosols or Calcarosols. These Orders have extreme morphological diversity and have been subject to extensive investigation, particularly in South Australia, south-west Western Australia and the Northern Territory.

This major change to the classification was subjected to widespread consultation within the Australian soil science community over 2 years. Feedback from this consultation was strongly positive but not universally so. However, it led to several constructive changes to the original proposal.

Changes in the third edition

The main change in the third edition accommodates new knowledge and understanding of the significance, nature, distribution and refined testing for soils comprising deep sands, leading to the inclusion of a new Order, the Arenosols. The introduction of the Arenosol Order led to a review and changes to Calcarosols, Tenosols and Rudosols.

Another significant change is the removal of the *weakly developed* tenic *B horizon* concept from the classification. Experience shows the concept is of little assistance in soil classification. It is not explicitly defined and therefore cannot be consistently determined, limiting its value as a classification criterion.

Small-scale indicative soil distribution maps have been added for each Soil Order. These maps are updates of the distribution maps found in the *Concepts and Rationale of the Australian Soil Classification* (Isbell *et al.* 1997). They are a re-interpretation of Ray Isbell's original assessment of the most likely Soil Order in each map unit of the 1:2 000 000 scale Atlas of Australian Soils (Northcote *et al.* 1960–1968), with allowance for subdominant occurrences in a map unit where the Soil Order is common but not dominant.

Guidance is now provided for soil classification at Great Group and Subgroup level where the diagnostic feature for a class begins more than 1.5 m below the soil surface.

The important points to note for the Orders affected, plus other improvements throughout the text, are summarised in Appendix 7.

Background

Classification is a basic requirement of all science and needs to be revised periodically as knowledge increases. It serves as a framework for organising our knowledge of Australian soils and provides a means of communication among scientists, and between scientists and those who use the land. The history of soil classification in Australia was reviewed by Isbell (1992), who noted that two classification schemes were in common usage at the time. The *Handbook of Australian Soils* (Stace *et al*. 1968) was largely a revision of the earlier great soil group scheme (Stephens 1953). The Factual Key (Northcote 1979) dates from 1960 and was essentially based on a set of ~500 profiles largely from south-eastern Australia. Moore *et al*. (1983) discussed the advantages and disadvantages of these two schemes. The history of the development of the *Australian Soil Classification* is presented in Appendix 6.

Over the past five decades a vast amount of soils data has accumulated. Since the first edition was published considerable new information has been collected in wetland environments, and in the Northern Territory and Western Australia. This information needed to be incorporated into any new or revised national soil classification. The second edition mainly accommodated new knowledge about acid sulfate soils (especially the sulfidic and sulfuric concepts), Subaqueous and Subtidal Hydrosols and introduced a new Sesqui-Nodular Suborder to the Tenosols. This third edition introduces a new Order for deep sands, the Arenosols.

It is important to note that reference to the frequency or likelihood of occurrence of certain soil classes throughout the key in previous editions was based on the data available at the time of the first edition's publication.

Several options were considered before deciding on the current form – a multi-categoric scheme with classes defined on the basis of diagnostic attributes, *horizons* or materials (collectively called *diagnostic features*) and their arrangement in vertical sequence as seen in an exposed *soil profile*. The emphasis was to be on soil attributes rather than geographic (or climate) attributes. In the new scheme, classes are based on real soil bodies, they are mutually exclusive, and the allocation of 'new' or 'unknown' individuals to the classes is by means of a key.

Most *diagnostic features* are defined in the glossary, and all definitions, where applicable, are consistent with usage in the *Australian Soil and Land Survey Field Handbook* (NCST 2009). The *Australian Soil and Land Survey Field Handbook* is referred to in this publication as the *Field Handbook* (the *Field*

Handbook is also colloquially known as the Yellow book due to the colour of its cover).

For clarity in this publication the levels in the classification are capitalised – for example Order, Suborder, Great Group, Subgroup and Family. This is not a requirement when using these terms outside of this publication.

The guiding principles are:

a) The classification should be a general purpose one as distinct from a technical or special purpose scheme.
b) The classification should be based on Australian soil data and as far as possible the selected attributes should have significance to land use and soil management.
c) The classification should be based on defined *diagnostic features*, the definitions of which, where appropriate, should be compatible with those of major international classification schemes.
d) The entity to be classified is the *soil profile*, with no depth restrictions in definition except for the 1.0 m depth criterion for the Arenosol Order.
e) Although the soil classification should be based as far as practicable on field morphological data, laboratory data must be used as appropriate. If possible, more use should be made of soil physical and engineering properties.
f) The scheme should be based on what is actually there rather than on what may have been present before disturbance by humans. Surface *horizons* should not be defined in terms of an 'after mixing' criterion as in *Soil Taxonomy* (Soil Survey Staff 2014).
g) The scheme should be a multi-categoric one, arranged in different levels of generalisation.
h) The scheme should be flexible enough to accept new knowledge as it becomes available – it should be open-ended.
i) The classification should give emphasis to relatively stable attributes as differentiae.
j) The nomenclature must not be too complex, but be unambiguous.

Applying principles b) and c) appropriately and consistently may prove difficult for some soils (e.g. assessing the relative importance of *diagnostic features*). In particular where *diagnostic features* are only observed at significant depth, judgement is required as to which principle should have precedence. Guidance to assist with this is provided in the key.

The guidelines above have been followed in the new scheme. Unfortunately, because of lack of data, it has not been possible to make more use of soil physical and engineering properties.

How to classify

What do we classify?

Soils are natural bodies consisting of *layers* or *horizons* of mineral and/or organic constituents of variable thickness which differ from their parent material in their morphological, physical, chemical and mineralogical properties and their biological characteristics (Birkeland 1984).

Because soils are three dimensional bodies their classification has always caused problems. In practice, in most countries, the entity classified is the *soil profile*, which is a vertical section through the soil from the surface through all of its *horizons* to the parent or substrate material. However, the lateral dimensions of the section may range from ~50 mm to a metre or more depending on the method of examination.

It is sometimes difficult to distinguish soil from its parent material or underlying substrate, and to distinguish between soil and 'not soil'. Most concepts of soil involve the idea of an organised natural body at the surface of the earth that serves as a medium for plant growth. However, most engineers and geologists tend to regard soils mainly as weathered rock or regolith. The first edition of *Soil Taxonomy* (Soil Survey Staff 1975) noted that the lower limit of soil is normally the lower limit of biological activity, which generally coincides with the common rooting depth of native perennial plants. There are obvious problems with the latter part of this concept, and in *Soil Taxonomy* the lower limit of the soil that is classified is arbitrarily set at 2.0 m. This approach is rejected in the *Australian Soil Classification*, and the term *pedologic organisation* (NCST 2009) is used to distinguish soil materials. This is a broad concept used to include all changes in soil material resulting from the effect of the physical, chemical and biological processes that are involved in soil formation. Results of these processes include horizonation, colour differences, presence of pedality, texture and/or consistence changes. Obviously there are some difficulties in this approach, such as distinguishing between a juvenile soil and recently deposited sedimentary parent material.

Subjective judgement is often required, as in distinguishing between the Rudosols with only rudimentary *pedologic organisation* as opposed to slight development in some Tenosols. In Rudosols and some Arenosols there will be negligible, if any, horizon development.

In the special case of the Anthroposols – the 'human-made' soils – some departure from the above concept of soil is necessary. In this Order *human* *activities* may have been mainly responsible for the creation of 'non-natural' parent materials as well as 'non-natural' alteration processes such as profound disturbance by mechanical or other means, or the addition of a wide range of anthropogenic materials to surface soils, including toxic chemical wastes.

Except for Anthroposols, the *Australian Soil Classification* is designed primarily for natural soils that have undergone at most, only minor change from *human activities*. However the classification of soils changed by the addition of liquids of variable attributes remains unresolved. The addition of liquid wastes, bore waters and other irrigation waters may alter the chemical and physical properties of soil substantially. For example, salts, acids, alkalis, suspended organic matter, nutrients and toxins in applied liquids may affect the *pH*, salinity, sodicity and fertility of the soil.

To be considered as a separate class of soil, the significant change from pre-waste conditions should extend throughout the entire *A horizon* and into at least the upper part of the *B horizon*. Soils changed in this way are not Anthroposols, but their changed nature could be acknowledged in the soil classification by describing the soil as a phase of the pre-existing soil class (e.g. saline phase, sodic phase or alkaline phase of a Brown Chromosol).

In classifying the *soil profile*, it is necessary to identify various *diagnostic features*. All terms used in the classification are consistent with those defined in the third edition of the *Field Handbook*, or else are defined in the glossary. As the *Field Handbook* is currently being revised, some definitions in the glossary are aligned with the proposed new *Field Handbook*, rather than the current (third) edition.

One of the most important features used in the classification is the *B horizon*. In some soils it may be present in variable amounts mainly in fissures in the parent rock or saprolite but even so it can still be of importance to use of the soil. The classification of such soils leads to a consideration of *transitional horizons* namely BC, B/C and C/B. If the *B horizon* material occupies more than 50% (visual abundance estimate) of the horizon (i.e. it is a *B*, *BC* or *B/C horizon*), the soil is deemed to possess a *B horizon* and is classified accordingly. If, however, the soil has a C/*B horizon* in which the *B horizon* component is between 10% and 50%, the soil would most likely be classed as a Tenosol. If there is less than 10% of *B horizon* material and no pedological development other than a minimal *A1 horizon*, the soil would most likely be classed as a Rudosol.

Although it is difficult to avoid genetic implications, it should be noted that a *B horizon*, for example, is identified by what it is, not by how it got there. Thus if there is a sequence where a sandy sedimentary *layer* overlies a clayey sedimentary *layer* and the system has been operating as a whole for sufficient time for soil forming factors to influence both, and also for the properties of one *layer* to influence the properties of the other, there is no reason why we cannot recognise these transformed *layers* as *A* and *B horizons* and classify the soil accordingly. Evidence of transformation can commonly be seen in the presence of an *A2 horizon* (which may be bleached) in the upper sandy sedimentary *layer* above a clay *layer*. If on the other hand, there is also a *B horizon* in the upper sandy *layer* (based on colour or texture) and there is still a clear or sharp boundary to the clay *layer* below, that would be considered a lithologic discontinuity (McDonald and Isbell 2009) and identified as a D horizon.

It is noted that accurate classification may require assessment of the *soil profile* at depth to determine the presence or maximum development of a *B horizon*. Inspection to commonly standardised maximum depths of 1.0 m or 1.5 m for particular survey purposes may not be sufficient. In such circumstances, confidence levels with the classification may be affected.

The *Australian Soil Classification* uses a set of defined attributes, *horizons* and materials in the key to assign a *soil profile* to a class. Collectively these concepts are called *diagnostic features*. *Diagnostic features* used in the key are ranked mainly on the basis of their likely importance to use of the soil. Ranking is subjective and arbitrary to a varying extent (Isbell *et al*. 1997).

Some *diagnostic features* occur at or near the soil surface or must occur within a specified *soil depth*. However, others do not have a depth criterion. Although the *Australian Soil Classification* has no depth restriction, at the Great Group and Subgroup levels it is permissible to consider whether a diagnostic feature that only begins at considerable depth should apply. As a guide, if the feature begins below 1.5 m, judgement on the impact of this feature on soil performance may need to be made. The class relating to this diagnostic feature may not be the only option in the key. If it is considered that this feature has minimal influence on the performance of the soil and there are other options in the key, it is permissible to consider the next option.

Another well known problem is how to deal with buried soils. No classification system has yet satisfactorily resolved this question. For the moment the approach adopted is a modified version of that used in *Soil Taxonomy* (Soil Survey Staff 2014). A buried soil may be overlain by another *soil profile* or by recently deposited material that has not had sufficient time to develop enough pedological features to meet any of the requirements for the defined Orders. In such cases the overlying material shall be regarded as a phase[1] of the classified soil below. Typical examples would be very recent silty or sandy alluvium deposited on a floodplain, windblown sand, or a recent *layer* of volcanic ash.

If the soil material overlying the buried soil is less than 0.3 m thick and has pedological development sufficient only to qualify as a Rudosol, then it is regarded as a depositional phase of the buried soil below. If the same overlying material is greater than 0.3 m thick it could be classified together with the buried soil as, for example, a Stratic Rudosol/Black Vertosol. If, however, the overlying material had sufficient pedological development for it to be classified other than as a Rudosol, it would be so classified irrespective of its thickness. An example would be Brown Tenosol/Black Vertosol.

[1] A recommended use of soil phase has been given by Powell (2008).

If a buried soil cannot be classified, the sequence may be recorded as in the following example: Grey Kandosol/sulfidic clayey D horizon. In this example the buried soil has a clayey texture, using the same texture categories as in the Family criteria.

Another situation which not uncommonly arises is the formation of a new soil in the *A horizon* of a pre-existing soil. This may also be covered as in the following example: Humosesquic, Semiaquic Podosol *f* Chromosolic, Redoxic Hydrosol. The symbol *f* indicates that the first named soil is forming in the *A horizon* of the second named soil.

Nature of the classification

The scheme is a general purpose, hierarchical one (Order, Suborder, Great Group, Subgroup, Family) and a diagrammatic view is shown in Fig. 1.

Note that this figure is a guide only and should not be used as a replacement for the complete key.

All hierarchical schemes have both advantages and disadvantages. Among the former is the flexibility to classify a soil at whatever level of generalisation is desired. A perceived disadvantage is that as soils are grouped into higher categories, the assertions that can be made about any group become progressively fewer. This explains why some high-level groupings, for example the Order Dermosols, can be criticised as containing a diverse range of soils. The goal of all successful hierarchical systems is to use criteria at the higher categories that carry the most accessory features along with those criteria.

Another related issue is some lack of consistency in the use of certain criteria in the hierarchy. The general philosophy has been to select differentiae which seem to reflect the most important variables within the classes. It would be tidy, for instance, to have all Suborders based on colour. The fact is that while it is useful to use colour at the Suborder level for nine of the Orders, it does not give the 'best' class differentiation for other Orders where different criteria give a more effective subdivision, for example in Podosols.

The fact that most classes are mutually exclusive inevitably means that soils on either side of a class boundary may appear to have more in common than they do with the 'central concept' of each adjoining class. An obvious example of this occurs in the Suborder classes defined by colour.

In general, intergrade soils are catered for at the Subgroup level. As an example, there are sodic and vertic Subgroups for Chromosols, which respectively indicate affinities with Sodosols and Vertosols. Another situation arises when similar soils are placed in different Orders because *B horizon pH* is say 5.3 in one soil and 5.6 in another; by definition the former soils are Kurosols and the latter Chromosols. However, the similarity between them is preserved by both Orders having essentially the same Suborders, Great Groups and Subgroups.

Several ideas have been taken from other classification schemes in Australia and overseas, for example the hierarchical framework of Order, Suborder, Great

A classification system for Australian soils

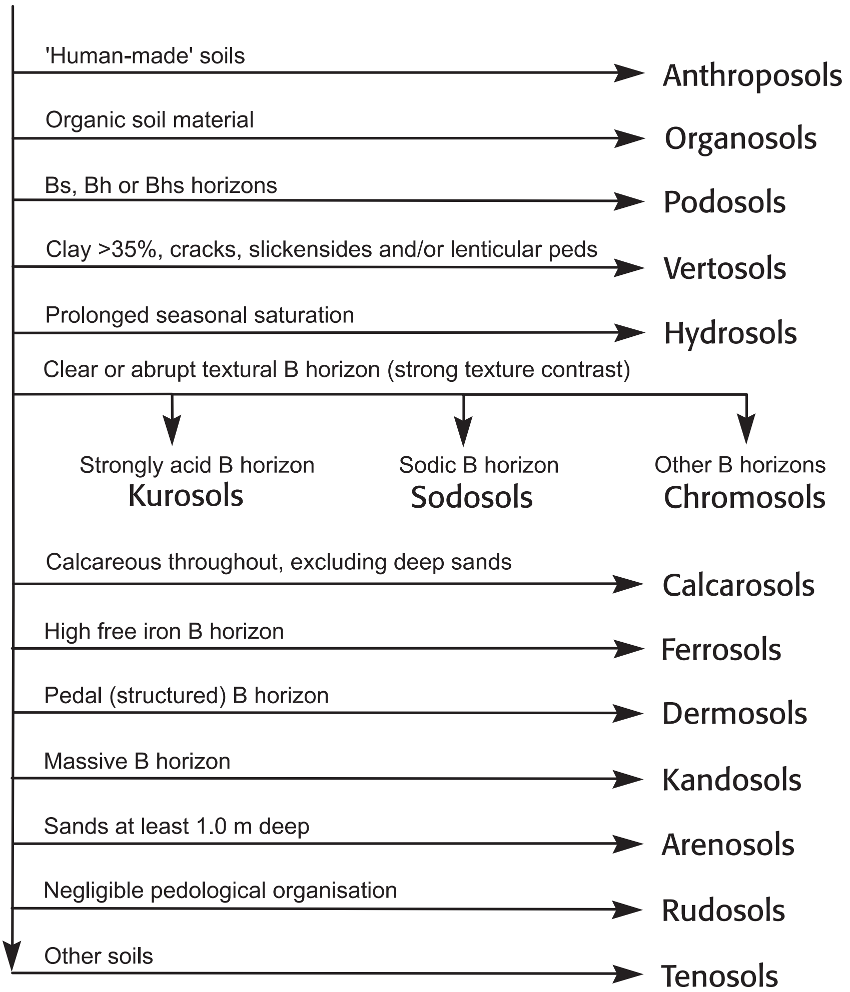


Fig. 1. Simplified key to the Orders.

Group, Subgroup and Family is widely used elsewhere in the world. Several concepts were borrowed from *Soil Taxonomy* (Soil Survey Staff 1975), and some originated in the South African classification (Soil Classification Working Group 1991), for example *base status* classes. Several concepts from the Factual Key (Northcote 1979) were also used, for example the use of strong texture contrast and colour at a high categorical level.

Throughout the text, where appropriate, brief reasons are given for particular decisions regarding the use of various differentiating criteria. These are found under the heading 'Comment'. Further explanation of many criteria is provided in Isbell *et al*. (1997). Appendix 5 shows approximate correlations between the

Orders of the new scheme and classes of two other classifications formerly used in Australia and two current international classifications.

A change from earlier Australian soil classification schemes is the use of laboratory data (mainly chemical) at some levels in several Orders. Although some field soil surveyors have protested, no apology is made for this approach. Soil classification schemes being developed around the world are increasingly relying on laboratory data, particularly where soils with very similar morphology may have widely differing chemical properties. The same is true for most other sciences (e.g. geology). In this scheme the need for laboratory data is minimised at the Order level, and where possible some guidelines are given to enable tentative field classification. A summary of the analytical requirements is given in Appendix 4.

Operation and nomenclature

The classification is designed in the form of several keys. To classify a *soil profile* the following procedure should be adopted.

1. Read the Key to the Soil Orders stepwise and select the first Order in the key that apparently includes the soil being studied, checking out diagnostic feature definitions in the glossary as needed.
2. Turn to the page indicated, read the definition of the Order to ensure that it embraces the soil being studied.
3. Then study the various keys to the Suborders, Great Groups and Subgroups, and select the first appropriate class where available. Note that the classes, particularly at the Subgroup level, must be examined sequentially, as they are often based on differentiating criteria which are thought to be of decreasing order of importance to the use of the soil. This of course is subjective, and the order in which the classes are arranged may be changed in the light of further knowledge.
4. If a diagnostic feature in the key at the Great Group and Subgroup level begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.
5. If a suitable class is not found at the Great Group or Subgroup level the classification at that level is not applied.
6. To classify at the Family level, select the appropriate designations.

The scheme is open ended; new classes can be added if desired, although they will not necessarily follow on from the existing classes. However the introduction of any new Orders will require substantial justification and testing. Where possible, names are connotative, and often based on Latin or Greek roots (e.g. see Table 2). Suborder, Great Group and Subgroup class names are given in bold type after each class definition, together with their relevant code.

Table 2. Soil Order nomenclature

Name of Order	Derivation	Connotation
Anthroposols	Gr. *anthropos*, man	'human-made' soils
Arenosols	L. *arena*, sand	sandy soils
Calcarosols	L. *calcis*, lime	*calcareous* throughout
Chromosols	Gr. *chroma*, colour	often bright coloured
Dermosols	L. *dermis*, skin	often with clay skins on ped faces
Ferrosols	L. *ferrum*, iron	high iron content
Hydrosols	Gr. *hydor*, water	wet soils
Kandosols	Kandite (1:1) clay minerals	–
Kurosols	–	pertaining to clay increase
Organosols	–	dominantly organic materials
Podosols	Rus. *pod*, under; *zola*, ash	podzols
Rudosols	L. *rudimentum*, a beginning	rudimentary soil development
Sodosols	–	influenced by sodium
Tenosols	L. *tenuis*, weak, slight	weak soil development
Vertosols	L. *vertere*, to turn	shrink-swell clays

There is a two letter code in brackets that is unique and follows each class name. The Order code is given after the Order heading. Similarly, a one or two letter code is given for the Family criteria. This code system allows recording on field sheets, and also enables various database searches to be carried out. As an example, it will allow searches for particular criteria irrespective of the hierarchical level at which they are used in the classification. Provision is also made for instances where there is no appropriate class available [code ZZ], or when it is not possible to determine the class from the available information [code YY]. Appendix 2 lists all the codes and equivalent class names used in the classification and Appendix 3 lists the level at which class names and their codes occur in the Soil Orders.

Provision is also made for indicating confidence levels of the classification where class definitions involve the need for analytical data and/or more morphological data. Appendix 1 demonstrates the use of codes and confidence levels in recording the classification of soil profiles.

The general form of the nomenclature is as follows:

Subgroup, Great Group, Suborder Order; Family.

An example is:

Bleached, Eutrophic, Red Chromosol; thin, gravelly, sandy/clayey, shallow, water repellent.

Note that the nomenclature can be shortened if desired, or if some levels of the hierarchy cannot be determined (e.g. Red Chromosol; Bleached, Red Chromosol; Red Chromosol; thin, gravelly).

At the Subgroup level in particular, the differentiating criteria are frequently not mutually exclusive. This problem can be alleviated to some extent by combining attributes, for example Bleached-Mottled, but usually judgement has been required in establishing the sequence of the Subgroup classes. This was largely based on a subjective assessment of the Subgroup properties in relation to use of the soil. In the seven Orders where the Haplic Subgroup is used it is placed last and defined as 'other soils with a whole coloured *B horizon*'. It should be noted that as well as having this particular property, it also does not have any of the properties of any class that precedes it in the list of Subgroups. This is the reason for the particular class name, derived from Gr. *haplous*, simple.

There are apparent inconsistencies in the use of *A* and *A1 horizons* at the Family level in various Orders. This is deliberate, for the following reasons. In the soils with strong texture contrast, it is thought that properties of the total *A horizons* (i.e. *A1*, *A2*, *A3*) are important. In some other Orders where soil changes are very gradual with depth, and it is frequently difficult to distinguish between say *A3* and *B1 horizons*, it is thought more appropriate to use *A1 horizon* at the Family level. In some circumstances problems may arise with *Ap horizons*. In the strong texture contrast situation above, the *Ap horizon* will automatically be included, although in some soils with thin *A horizons* or where deep ploughing is practised, there is the probability that some of the *B horizon* will be incorporated in the *Ap horizon*. In the case of *A1 horizons*, these will mostly equate with *Ap horizons*, although again there can be a problem with deep ploughing. In some *A* and *A1 horizons*, texture may not be uniform throughout. In these instances the texture of the *major part* of the horizon should be given.

Some soils may have surface *horizons* dominated by *organic materials* (*O2* or *P horizons*; *Field Handbook*) which overlie *A horizons*. In these cases the *field texture* at the Family level will be given for the *O2* or *P horizon* (i.e. peaty). In soils with Peaty or Subpeaty Subgroups this will result in repetition at the Family level. See also *peaty horizon* in glossary.

At the Family level all textures are *field texture*s and *soil depth* is measured from the soil surface, including any *O2*, *P1* or *P2 horizons*, if present. The clay percentages given in brackets are merely a guide and are based on those in the *Field Handbook*. In contrast, the clay content classes used in Vertosols are based on actual laboratory analyses.

Concluding statement

Three points concerning use of the classification need to be emphasised. First, the best place to classify a soil is in the field, where the morphological requirements can readily be checked. Even if laboratory data are required for some classes, a tentative classification can usually be made and verified later. It is important therefore to always give the confidence level of the classification (see Appendix 1). Second, to quote the South African Soil Classification Working Group (1991), 'this soil classification has as its primary aim the identification and naming of soils according to an orderly system of defined classes, and so permit communication about soils in an accurate and consistent manner.' Third, in the case of soil survey and mapping, the use of the scheme will not be any different to that of any existing classification; it must be coupled to soil mapping for it to yield information on the geographic distribution of soils. Recommendations for classification and mapping units in Australian soil surveys are provided by Powell (2008).

Finally, it should again be emphasised that no classification scheme is ever complete. As knowledge increases, so there must be future modifications to the scheme to incorporate this new knowledge. In this classification this axiom is particularly relevant in the case of the Anthroposols where at present data are very limited. Amendments to the classification are the responsibility of the National Committee on Soil and Terrain, which has representatives from relevant Territory, State and Commonwealth agencies.

Key to Soil Orders

The material below is arranged to give the simplest way of identifying a particular soil in terms of the Orders, and is not a complete definition of each Order. Work successively through the key until an apparent identification is made, then check the full definition of the Order by going to the relevant Order page.

Key words or phrases are defined in the glossary (indicated by *italics*).

A. Soils resulting from *human activities* which have caused a profound modification, mixing, truncation or burial of the original soil *horizons*, or the creation of new soil parent materials. ANTHROPOSOLS (p. 15)

B. Soils that are not regularly inundated by saline tidal waters and either:
   1. Have more than 0.4 m of *organic materials* within the upper 0.8 m. The required thickness may either extend down from the surface or be taken cumulatively within the upper 0.8 m, or
   2. Have *organic materials* extending from the surface to a minimum depth of 0.1 m; these either overlie a mineral soil horizon or unconsolidated mineral material no thicker than the *organic materials* above, or directly overlie rock or other *hard layers*, partially weathered or decomposed rock or saprolite, or overlie fragmental material such as *gravel*, cobbles or stones in which the interstices are filled or partially filled with *organic material*. In some soils there may be *layers* of *humose*, *melacic* and/or *melanic horizon* material underlying the *organic materials* and overlying the substrate. ORGANOSOLS (p. 79)

C. Other soils that have a *Bs*, *Bhs* or *Bh horizon* (see *Podosol diagnostic horizons*). These *horizons* may occur either singly or in combination. PODOSOLS (p. 85)

D. Other soils that:
   1. Have a clay *field texture* or 35% or more clay throughout the *solum* except for thin, surface crusty *horizons* 30 mm or less thick, and
   2. Unless too moist, have open cracks at some time in most years that are at least 5 mm wide and extend upward to the surface or to the base of any plough *layer*, *peaty horizon*, self-mulching horizon, or thin, surface crusty horizon, and
   3. At some depth in the *solum*, have *slickensides and/or lenticular peds*. VERTOSOLS (p. 116)

E. Other soils that are saturated in the *major part* of the *soil profile* for at least 2–3 months in most years (i.e. includes tidal waters). HYDROSOLS (p. 52)

F. Other soils with a *clear or abrupt textural B horizon* and in which the *major part* of the upper 0.2 m of the B2t horizon (or the *major part* of the entire B2t horizon if it is <0.2 m thick) is *strongly acid*. KUROSOLS (p. 74)

G. Other soils with a *clear or abrupt textural B horizon* and in which the *major part* of the upper 0.2 m of the B2t horizon (or the *major part* of the entire B2t horizon if it is <0.2 m thick) is *sodic* and is not strongly *subplastic*. SODOSOLS (p. 98)

H. Other soils with a *clear or abrupt textural B horizon* and in which the *major part* of the upper 0.2 m of the B2t horizon (or the *major part* of the entire B2t horizon if it is <0.2 m thick) is not *strongly acid*. CHROMOSOLS (p. 35)

I. Other soils that:
   1. Are either *calcareous* throughout the *solum* – or *calcareous* at least directly below the *A1* or *Ap horizon*, or a depth of 0.2 m (whichever is shallower). Carbonate accumulations must be judged to be pedogenic, that is, are a result of soil forming processes *in situ* (either current or relict). Soils dominated by non-pedogenic *calcareous* materials such as fragments of limestone or shells are excluded (see also *calcrete*), and
   2. Do not have deep sandy profiles that have a *field texture* of sand, loamy sand or clayey sand in 80% or more of the upper 1.0 m.

   CALCAROSOLS (p. 28)

J. Other soils with *B2 horizons* in which the *major part* has a *free iron oxide* content greater than 5% Fe in the *fine earth* fraction (<2 mm). Soils with a *B2 horizon* in which at least 0.3 m has *vertic properties* are excluded (see also Comment in Ferrosols). FERROSOLS (p. 48)

K. Other soils with *B2 horizons* that have *grade of pedality* greater than weak throughout the *major part* of the *horizon*. DERMOSOLS (p. 41)

L. Other soils that:
   1. Have *B2 horizons* in which the *major part* has a *grade of pedality* that is massive or weak, and
   2. Have a maximum clay content in some part of the *B2 horizon* that exceeds 15% (i.e. heavy sandy loam [SL+] or heavier). KANDOSOLS (p. 67)

M. Other soils that have, within the upper 1.0 m of the *soil profile*:
   1. A sandy *field texture* (i.e. a *field texture* of sand, loamy sand or clayey sand) in one or more *layers* or *horizons* with a combined thickness of at least 0.8 m, and
   2. No *layer* or horizon with a clay content that exceeds 15% (i.e. heavy sandy loam [SL+] or heavier) excluding *argic horizon*/s, and
   3. ≤10% (by visual abundance and weighted average) of coarse fragments and/or *hard* segregations >2 mm in size, and
   4. No *hard layers* (*cemented pans*, other cemented materials, rock, saprock or saprolite). ARENOSOLS (p. 19)

N. Other soils with negligible (rudimentary), if any, *pedologic organisation* apart from the minimal development of an *A1 horizon* or the presence of less than 10% of *B horizon* material (including pedogenic carbonate) in fissures in the parent rock or saprolite. The soils have a *grade of pedality* of single grain, massive or weak in the *A1 horizon* and show no pedological colour change apart from darkening of an *A1 horizon*. There is little or no texture or colour change with depth unless stratified or buried soils are present. *Cemented pans* may be present as a substrate material. Soil may be shallow over unrelated rock. RUDOSOLS (p. 91)

O. Other soils. TENOSOLS (p. 104)

Anthroposols [AN]

[Pronounced An-throp-oh-sols]

Concept

These soils result from *human activities* which have caused a profound modification, mixing, truncation or burial of the original soil *horizons*, or the creation of new soil parent materials. Note that the concept of soil used in this classification of Australian soils (see Background) also applies to the Anthroposols, and hence sealed and semi-sealed surfaces such as streets and roads are regarded as 'non-soil'. Also, in depositional situations, the anthropic material must be 0.3 m or more thick where it overlies buried soils. A soil with anthropic materials less than 0.3 m thick should be classified as an anthropic phase of the underlying soil.

To qualify as soil an Anthroposol needs to possess some pedogenic features, as noted below. Key criteria in the identification of an Anthroposol are the presence of artefacts in the profile or knowledge that the soils or their parent materials have been made or altered by human action.

Anthroposols differ from other soils in that we normally know their origin with a degree of certainty, and hence we can invoke a knowledge of process rather than defined pedogenic attributes to initially classify the soil. We can then subdivide at the higher levels on the basis of type of process and nature of the product which forms the parent material of the new soil. At lower levels in the classification, conventional soil properties could be used when available, although obviously these will be limited in very young soils.

Definition

Soils resulting from *human activities* which have led to a profound modification, truncation or burial of the original soil *horizons*, or the creation of new soil parent materials by a variety of mechanical means. Where burial of a pre-existing soil is involved, the anthropic materials must be 0.3 m or more thick. Pedogenic features may be the result of *in situ* processes (usually the minimal development of an *A1 horizon*, sometimes the stronger development of typical soil *horizons*) or the result of pedogenic processes before modification or placement (i.e. the presence of identifiable pre-existing soil material).

Comment

It is difficult to quantify 'profound modification, mixing and truncation' but this would normally exclude the usual agricultural operations (including land planing) which may change a soil from say a Chromosol to a Dermosol by mixing or removal of the upper *horizons*. Similarly, soils that are artificially drained or flooded are not Anthroposols but may classify as different Orders following a permanent change in water status (see also comment in Hydrosols).

There will be instances where the question is how much truncation results in 'profound modification' or merely a truncated phase. It is difficult to give guidelines that will cover all circumstances, and inevitably judgement is required. Similarly, there will be instances where land reclamation and restoration in the past have been so successful that little evidence of a prior disturbance remains, and soil development gives no clue to past history. A good example of this is Podosol development on restored and revegetated coastal dunes following sand mining.

Suborders

••• Soils that have surface *layers* at least 0.3 m thick that show evidence of burnt *peat* (often in the form of coloured *ash material*) and comprise ≥20% of fusic soil material. **Fusic [IT]**

••• Soils that have been formed by applications of human-deposited materials such as mill-mud or the accumulation of shells and *organic materials* to form middens. (Minimum thickness of deposit or accumulation is 0.3 m.) **Cumulic [HR]**

••• Soils that have had additions of organic residues such as organic wastes, composts or mulches that have been incorporated into the soil and obliterated pre-existing pedological features. **Hortic [HS]**

••• Mineral soil or regolithic materials that are underlain by land fill of manufactured origin and which is predominantly of an organic nature. These materials may be of domestic or industrial origin and usually occur as artificially elevated landforms. The intent is to designate refuse from human activity high enough in organic matter to generate significant quantities of methane when placed under anaerobic conditions. **Garbic [HT]**

••• Mineral soil or regolithic materials that are underlain by land fill of predominantly a mineral nature. The fill may be wholly of manufactured origin (glass, plastics, concrete, etc.) or contain a mixture of manufactured materials and materials of pedogenic origin. The fill usually occurs as an artificially elevated landform. **Urbic [HU]**

••• Soils that have formed or are forming on mineral materials that have been dredged through human action from the sea or other waterways, or deposited as a slurry resulting from mining operations (e.g. tailings ponds, salt ponds, coal washing residues). The dredged materials commonly occur as a lithologically distinctive unit overlying (buried) floodplain surfaces. Such deposits frequently occur in coastal areas, common examples being airports, golf courses and other urban developments. **Dredgic [HV]**

••• Soils that have formed or are forming on mineral materials that have been moved by earthmoving equipment in mining, highway construction, dam building, etc. The materials contain too few manufactured artefacts to qualify as urbic soils. Landscapes are human-formed, and hence may present an 'unnatural' geomorphic expression. Spolic materials are increasingly being capped by pre-existing topsoil. **Spolic [HW]**

••• Soils that have formed or are forming on land surfaces that have been created by humans by cutting away any previously existing soil by mechanical equipment such as bulldozers and graders. Common occurrences are found along highways and hillside urban development where they are usually associated with fill areas with spolic materials. In some instances truncated remnants of the lower *horizons* of pre-existing soils may occur. Scalpic soil areas typically have peculiar geomorphic expressions, often with smooth and steep slopes. **Scalpic [HX]**

Comment

In the Garbic, Urbic and some Spolic soils it is common practice to cover the anthropic materials with a *layer* of soil materials as an aid to reclamation. This soil material is regarded as part of the Suborder and can be used as a basis for lower category classification. In other situations sewage sludge is being used to rehabilitate mine spoil.

Scalpic soils may also have material added to their new surface. If this is less than 0.3 m there would be, for example, a spolic phase of the Scalpic Suborder; if 0.3 m or more thick the soil would classify as a Spolic Suborder.

There will obviously be intergrade situations between some of the Suborders. For example, it may sometimes be difficult to decide between Garbic and Urbic, Cumulic and Hortic. In these and similar situations judgement and/or knowledge of the process will be required. With the increasing emphasis on recycling, much of the garbic materials will be composted so the Garbic Suborder could become redundant.

Another likely difficult situation results when human-induced or human-accelerated erosion has removed upper soil *horizons*. On present thinking it would seem more appropriate for such soils to be regarded as an eroded phase of say a Sodosol, provided the original soil can be identified.

The question of soils contaminated by toxic wastes is also unresolved. They could be included in the Garbic Suborder, but if the wastes are toxic to plant and animal life their host materials cannot strictly be regarded as soil. In some situations the problem could be overcome by referring to the site as a contaminated phase of the pre-existing soil. Similarly the application of liquid wastes, bore water and other irrigation waters may alter the chemical and physical properties of soil substantially. For example, salts, acids, alkalis, suspended organic matter, nutrients and toxins in applied liquids may affect the *pH*, salinity, sodicity and fertility of the soil. These soils could be identified as a phase of the pre-existing soils, for example saline phase, sodic phase or alkaline phase.

Lower categories

It is hoped that the seven Suborders will provide a conceptual framework for the classification of most anthropic soils based on human-induced processes which provide particular kinds of soil parent materials. The Suborders are a simplified relevant summary of an almost infinitely large range of anthropic processes and products. The need for subdivision below the Suborder level is likely to be more desirable in some classes than others, but a major problem in creating lower category classes is the lack of data on the morphology and laboratory properties of anthropic soils. Most information seems to be available for the spolic soils created by mining operations. Here though it may be more appropriate to create a technical classification based on reclamation needs.

For some of the Suborders, differentiae for lower categories could be based on appropriate traditional attributes used in classifying 'natural' soils, both morphologic and laboratory-determined. At present this is impractical due to the lack of an adequate representative profile database. A related approach is to use at the Great Group level classes based on the other Orders (e.g. Chromosolic, Sodosolic), as has been done for the Hydrosol Great Groups. In this approach Rudosolic Spolic Anthroposols would obviously be a very common class. A wide range of options is available for Subgroup differentiae, but existing Family criteria will probably be appropriate for most Anthroposols. A preliminary approach to classifying Australian mine soils based on proposed amendments to *Soil Taxonomy* has been made by Fitzpatrick and Hollingsworth (1994). Several of their proposed Subgroups could be used in Spolic Anthroposols, and some examples are given in their paper.

Until more knowledge and experience is available, it is proposed not to formalise the classification of Anthroposols below the Suborder level. Acknowledgment is due to Fanning and Fanning (1989) for several of the concepts and terminology used in this preliminary classification of Anthroposols.

Arenosols [RE]

[Pronounced Ah-ren-oh-sols]

Concept

The core concept of this Order is 'deep sandy soils'.

Arenosols accommodate soils with predominantly sandy *field texture*s (≤10% clay content), and with no *horizons* containing more than 15% clay within the upper 1.0 m of the profile. The presence of *argic horizons* is the only exception. Arenosols generally have no observable peds apart from some structural development in the *A1 horizon*. The upper 1.0 m of the *soil profile* can only contain relatively small amounts of coarse fragments or coarse, *hard* segregations and does not contain any *hard layers* such as pans or rock. Arenosols occur extensively in inland arid areas, in and adjacent to waterways, near to the coast (especially in the west), but are also present in many other parts of Australia. This Order incorporates the most widespread and abundant soils in Australia.

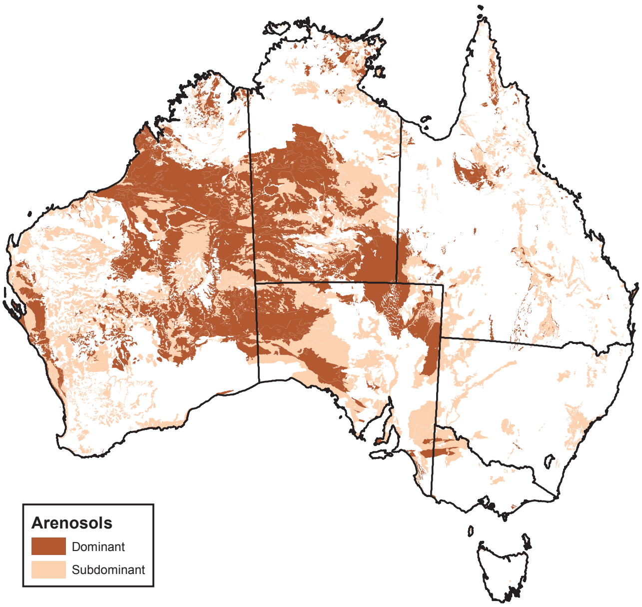
Definition

Soils that have, within the upper 1.0 m of the *soil profile*:

1. A sandy *field texture* (i.e. a *field texture* of sand, loamy sand or clayey sand) in one or more *layers* or *horizons* with a combined thickness of at least 0.8 m, and
2. No *layer* or horizon with a clay content that exceeds 15% (i.e. heavy sandy loam [SL+] or heavier) excluding *argic horizon*/s, and
3. ≤10% (by visual abundance and weighted average) of coarse fragments and/or *hard* segregations >2 mm in size, and
4. No *hard layers* (*cemented pans*, other cemented materials, rock, saprock or saprolite)

Comment

As *B horizons* are difficult to identify consistently in some Arenosols, specific mention of a *B horizon* is omitted from some Suborders. Arenosols will obviously grade to Kandosols and some difficulty may be experienced in separating them. Here Kandosols must have a clearly distinguishable, well developed *B2 horizon* with more than 15% clay whereas Arenosols have less than 15% clay.



Distribution of Arenosols in Australia.

Reclassification may also be required for other sandy soils where deep examination below 1.0 m reveals deep more clayey *B horizons*. See How to Classify for assistance with determining whether the *layer* is a B or D horizon. If the *layer* is a D horizon, the soil remains classified as an Arenosol.

Bleached or Grey Arenosols are distinguished from Podosols by the absence of *Podosol diagnostic horizons*. These *horizons* can occur below 1.0 m deep and commonly at considerable depth. If no deep examination has been done in similar soils in similar environments, then the soil should classify as a Bleached or Grey Arenosol with a confidence level of 4. If evidence at a later date reveals the presence of *Podosol diagnostic horizons* at depth, the soil will need to be reclassified.

Some Arenosols may include one or more thin *argic horizons* (also termed *lamellae*) which are usually 5–10 mm thick.

Arenosols will also grade to Tenosols. This third edition of the *Australian Soil Classification* reflects a major change to the Tenosol Order. Many sandy soils previously classified as the colour-linked Orthic Suborders of Tenosols will now classify as Arenosols.

As the Arenosols Order includes soils with negligible development many deep sandy soils previously described as Rudosols will now classify as Arenosols.

This third edition of the *Australian Soil Classification* also reflects a significant change to the Calcarosol Order. Many deep sandy soils with pedogenic carbonates previously classified as Shelly, Calcic or Hypocalcic Calcarosols will now classify as Carbonatic or Calsilic Arenosols.

Suborders

••• Soils that are not highly saline (EC <2 dS m^{-1}; 1:5 H_2O) and dominantly consist of sand-sized gypsum crystals. These crystals may not feel like sands when hand texturing due to their partial dissolution in water. **Hypergypsic [FJ]**

••• Soils that are highly saline (EC >2 dS m^{-1}; 1:5 H_2O), often salt-encrusted, frequently stratified, but do not have a permanent or seasonal water table and do not show any evidence of episodic wetting by groundwater, such as mottling. **Hypersalic [CS]**

••• Soils with a *peaty*, *humose*, *melacic* or *melanic horizon*. A *conspicuously bleached A2 horizon* is not present. **Chernic [BE]**

••• Soils that are *calcareous* throughout (at least in the upper 1.0 m of the *soil profile*). The upper 0.1 m of the *soil profile* consists of dominantly fine-earth carbonate (visual estimate) and/or contains more than 40% (by analysis) of *fine earth* carbonate. **Carbonatic [JT]**

••• Other soils that are *calcareous* throughout (at least in the upper 1.0 m of the *soil profile*), or *calcareous* at least directly below the A1 or *Ap horizon* or a depth of 0.2 m (whichever is the shallower). **Calsilic [JN]**

••• Soils that consist dominantly of *unconsolidated mineral materials* that are distinct, not or only slightly gravelly (<10% >2 mm) sedimentary *layers* or buried soils but salinity is not high (EC <2 dS m^{-1}; 1:5 H_2O). **Stratic [ER]**

••• Soils with a *conspicuously bleached A2 horizon*. **Bleached [AT]**

Soils in which the dominant colour class in the *major part* of the upper 1.0 m of the *soil profile* is:

••• Red. **Red [AA]**
••• Brown. **Brown [AB]**
••• Yellow. **Yellow [AC]**
••• Grey. **Grey [AD]**
••• Black. **Black [AE]**

Comment

The Hypergypsic soils normally occur as gypsum lunettes and the Hypersalic soils are most common in many of the saline playas of the arid interior of the continent. The Chernic soils typically occur in low lying, wetter, cooler areas of southern Australia where organic matter accumulates in surface *horizons*. The Carbonatic and Calsilic soils occur on many coastal dunes with Calsilic soils also common in the mallee of southern Australia. The Bleached, Red, Brown, Yellow, Grey and Black soils mainly cater for the widespread siliceous dunes and sandsheets, as well as some coastal dunes. The Stratic soils occur where sands have been deposited through water action.

The Carbonatic soils are typically highly *calcareous* and dominated by sand-sized *fine earth* carbonates throughout the profile. The Carbonatic Suborder in Arenosols partially replaces the former Shelly Suborder in Calcarosols. Other shelly soils are now restricted to soils dominated by shell fragments in Rudosols.

The Calsilic Suborder includes sands that are *calcareous* throughout (with the possible exception of the surface) but are generally lower in carbonates and more siliceous than the Carbonatic Suborder.

The most commonly recorded Suborders are Carbonatic, Calsilic, Bleached, Red, Brown, Yellow and Grey.

Great Groups

No Great Groups are presently proposed for the Hypergypsic and Stratic Suborders as data are limited, plus the limited pedological development of these soils means that subsoils are generally only *weakly developed*.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

Hypersalic Arenosols

- Soils in which *sulfuric material* (at least 0.15 m thick) occurs within the upper 1.5 m of the *soil profile*. **Sulfuric [EV]**

  Note: The Sulfuric Great Group can be replaced by the following Great Group where appropriate evidence is available:

- Soils in which both *monosulfidic materials* and *sulfuric material* (at least 0.15 m thick) occur within the upper 1.5 m of the *soil profile*. **Monosulfidic-Sulfuric [IW]**
- Soils in which *sulfidic materials* occur within the upper 1.5 m of the *soil profile*. **Sulfidic [EU]**

  Note: The Sulfidic Great Group can be replaced by the following Great Groups where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *hypersulfidic material* occur within the upper 1.5 m of the *soil profile*. **Monohypersulfidic [IX]**
- Other soils in which *hypersulfidic material* occurs within the upper 1.5 m of the *soil profile*. **Hypersulfidic [IZ]**
- Soils in which both *monosulfidic material* and *hyposulfidic material* occur within the upper 1.5 m of the *soil profile*. **Monohyposulfidic [JA]**
- Other soils with *hyposulfidic material* within the upper 1.5 m of the *soil profile*. **Hyposulfidic [JC]**

- •• Sols with a *gypsic horizon* within the upper 1.0 m of the *soil profile*. Gypsic [BZ]
- •• The *major part* of the upper 0.5 m of the *soil profile* consists of materials dominated (>50%) by halite crystals. Halic [CC]
- •• The *major part* of the upper 0.5 m of the *soil profile* consists of materials with <50% halite crystals. Subhalic [JK]

Chernic Arenosols

Suitable Great Groups may be found as listed for Bleached and coloured Arenosols

Carbonatic and Calsilic Arenosols

The Great Groups that include *hard layers* (*cemented pans*, other cemented materials, rock, saprock or saprolite) can only apply to *layers* that occur below 1.0 m.

- •• Soils with an *argic horizon*. Argic [AP]
- •• Soils with a *gypsic horizon*. Gypsic [BZ]
- •• Soils that are not *calcareous* in the A1 or *Ap horizon*, or to a depth of 0.2 m if the *A1 horizon* is only *weakly developed*. Epibasic [IB]
- •• Soils in which the upper 0.1 m of the *soil profile* consists of more than 20% *fine earth* carbonate (visual estimate using a 10 × hand lens), and/or has a strong effervescence with 1 M HCl, and/or contains more than 8%[2] (by analysis) of *fine earth* carbonate. Hypervescent [CP]
- •• Soils that directly overlie *marl*. Marly [DD]
- •• Soils that directly overlie a *red-brown hardpan*. Duric [BJ]
- •• Soils that directly overlie a *calcrete pan*. Petrocalcic [DZ]
- •• Soils that directly overlie *hard* rock. Lithic [CZ]
- •• Soils which directly overlie partially weathered or decomposed rock or saprolite. Paralithic [DU]
- •• Soils that directly overlie *unconsolidated mineral materials*. Regolithic [GF]

Comment

Epibasic and Hypervescent Great Groups are only applicable to the Calsilic Suborder.

[2] Based on numerous *fine earth* analyses by Primary Industries, South Australia.

Chernic, Bleached, Red, Brown, Yellow, Grey and Black Arenosols

The Great Groups that include *hard layers* (*cemented pans*, other cemented materials, rock, saprock or saprolite) can only apply to *layers* that occur below 1.0 m. In Great Groups that include a *ferric horizon* overlying a *hard layer* (i.e. Ferric-Duric, Ferric-Petroferric and Ferric-Reticulate) the *ferric horizon* may begin within the top 1.0 m.

- Soils that have a *ferric horizon* and overlie a *red-brown hardpan*. Ferric-Duric [FK]
- Other soils that overlie a *red-brown hardpan*. Duric [BJ]
- Soils that contain a *ferric horizon* and which overlie *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Ferric-Petroferric [GE]
- Soils that contain a *ferric horizon* and which overlie a *reticulate horizon*. Ferric-Reticulate [IS]
- Other soils that overlie *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Petroferric [EA]
- Soils that overlie a *reticulate horizon*. Reticulate [EF]
- Soils that overlie a *siliceous pan*. Silpanic [EM]
- Other soils with a *ferric horizon*. Ferric [BU]
- Soils with a *bauxitic horizon*. Bauxitic [AS]
- Soils with a *manganic horizon*. Manganic [DC]
- Soils that have *andic properties* and have formed in basaltic *tephric materials* that may be visibly stratified. Andic [AK]
- Soils that have formed in *tephric materials* that may be visibly stratified. Tephric [HF]
- Soils with an *argic horizon*. Argic [AP]
- Soils in which the *major part* of the upper 1.0 m has a distinct *gritty* feel. Gritty [JQ]
- Soils with a *gypsic horizon* in the upper 1.0 m of the *soil profile*. Gypsic [BZ]
- Soils in which the *major part* of the upper 1.5 m of the *soil profile* consists of visible heavy or opaque minerals (>3%) that may also be visibly stratified (identifiable by *wet panning* in the field). Gravic [JR]
- Soils in which the *fine earth* carbonate is evident only as a slight to moderate effervescence (1 M HCl), and/or contain less than 2% *fine earth* carbonate, and have less than 20% *hard* carbonate nodules or concretions. Hypocalcic [CV]

- Soils with a *calcareous horizon* containing more than 50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. **Lithocalcic [DA]**
- Soils with a *calcareous horizon* containing 20–50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. **Supracalcic [FB]**
- Soils with a *calcareous horizon* containing more than 20% of *fine earth* carbonate, and 0–20% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions, and/or carbonate-coated *gravel*. **Hypercalcic [CQ]**
- Other soils with a *calcareous horizon* containing *fine earth* carbonate. **Calcic [BD]**
- Soils that overlie a *hard*, *calcrete pan*. **Petrocalcic [DZ]**
- Soils with a transitional horizon (C/B) occurring in fissures in the parent rock or saprolite that contains between 10 and 50% of *B horizon* material (including pedogenic carbonate). **Inceptic [IA]**
- Soils that overlie *hard* rock. **Lithic [CZ]**
- Soils that overlie partially weathered or decomposed rock or saprolite. **Paralithic [DU]**
- Soils that overlie *marl*. **Marly [DD]**
- Soils with a *layer* or horizon, other than the surface horizon, that has a light sandy loam texture (~10–15% clay) that begins within the upper 1.0 m of the *soil profile*. Kandic Arenosols have affinities with Kandosols but are too sandy. **Kandic [JP]**
- Soils with a *layer* or horizon, other than the surface horizon, that has a clayey sand or loamy sand texture (~5–10% clay) that begins within the upper 1.0 m of the *soil profile*. **Tenic [JL]**
- Other soils that, other than the surface horizon, have a sand texture (<5% clay) throughout at least the upper 1.0 m of the *soil profile*. **Palic [FH]**

Comment

The *calcareous* classes above approximately correspond to those of Wetherby and Oades (1975) as follows: Hypocalcic – Class IV, Lithocalcic – Class III B and IIIC, Supracalcic – Class III B, Hypercalcic – Class III A, Calcic – Class 1 and IIIA. In the Lithocalcic and Supracalcic classes the coarse fragments may be >0.2 m in size and soft carbonate may or may not be present.

Subgroups

No Subgroups are proposed for the Hypergypsic, Hypersalic, Carbonatic, Calsilic and Stratic Suborders. The Humose-Calcareous, Melanic-Calcareous and Calcareous Subgroups are not required for the Hypocalcic, Lithocalcic, Supracalcic, Hypercalcic, Calcic and Petrocalcic Great Groups.

Subgroups of Chernic, Bleached, Red, Brown, Yellow, Grey and Black Arenosols

- Soils with a *peaty horizon*. Peaty [DW]
- Soils with a *humose horizon* and the *major part* of the upper 1.0 m of the *soil profile* is *strongly acid*. Humose-Acidic [GY]
- Soils with a *humose horizon* and at least some part of the upper 1.0 m of the *soil profile* is *calcareous*. Humose-Calcareous [GU]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon* and the *major part* of the upper 1.0 m of the *soil profile* is not *strongly acid*. Melacic-Basic [FU]
- Other soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon* and the *major part* of the upper 1.0 m of the *soil profile* is *strongly acid*. Melanic-Acidic [FV]
- Soils with a *melanic horizon* and at least some part of the upper 1.0 m of the *soil profile* is *calcareous*. Melanic-Calcareous [FC]
- Other soils with a *melanic horizon*. Melanic [DK]
- Soils with all the requirements for a *peaty horizon* except the thickness. Subpeaty [ID]
- Soils in which the *major part* of the upper 1.0 m of the *soil profile* is *strongly acid*. Acidic [AI]
- Soils in which at least some part of the upper 1.0 m of the *soil profile* is *calcareous*. Calcareous [BC]
- Other soils that are not *strongly acid* and are not *calcareous*. Basic [AR]

Family Criteria

Use of the term *A horizon* may be inappropriate for some of these soils because of either minimal development due to an arid environment, or common surface *deflation* or accumulation caused by wind. Hence it is thought better to use the term surface soil for texture and to delete the thickness criteria. In general, surface soil in this context will probably be in the range of 0.1–0.2 m in thickness.

Gravel of the surface and/or *A1 horizon*

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

Surface soil texture

Peaty	[J]	Dominated by *organic materials*
Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)

Maximum texture below the surface or *A1 horizon* (within the upper 1.0 m of the soil profile)

Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)

Soil depth

Deep	[W]	1.0–<1.5 m
Very deep	[X]	1.5–5 m
Giant	[Y]	>5 m

Water repellence of surface soil

Non water repellent	[NR]	Water absorbed in 10 seconds or less
Water repellent	[WR]	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	[SR]	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

Calcarosols [CA]

[Pronounced Cal-care-oh-sols]

Concept

The soils in this Order are usually *calcareous* throughout the *soil profile*, often highly so. They constitute a widespread and important group of soils in southern Australia.

Definition

Soils that:

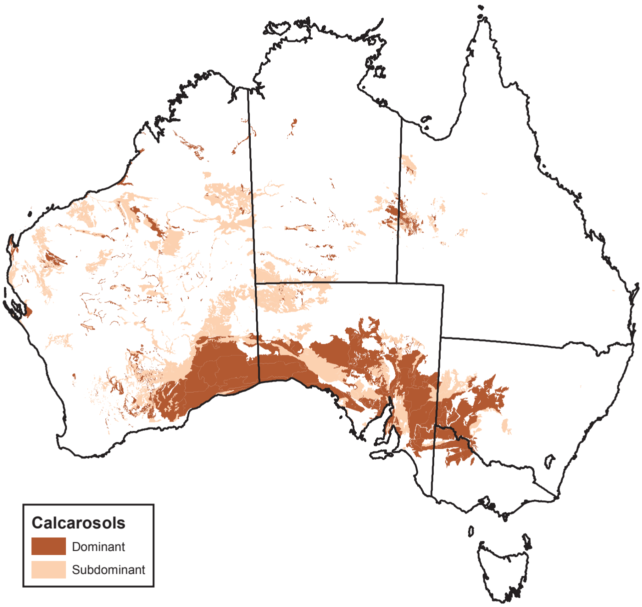
1. Are either *calcareous* throughout the *solum* – or *calcareous* at least directly below the A1 or *Ap horizon*, or a depth of 0.2 m (whichever is shallower). Carbonate accumulations must be judged to be pedogenic,[3] that is, are a result of soil forming processes *in situ* (either current or relict). Soils dominated by non-pedogenic *calcareous* materials such as fragments of limestone or shells are excluded. See also *calcrete*, and
2. Do not have deep sandy *soil profile*s that have a *field texture* of sand, loamy sand or clayey sand in 80% or more of the upper 1.0 m.

Comment

A difficulty may arise in separating those Calcarosols that are not *calcareous* throughout from *calcareous* Kandosols and from Tenosols containing pedogenic carbonate. However, in the latter two soils it is usual for the carbonate to occur in the lower part of the *B horizon*, and not immediately below the *A horizon*. Even so, transitional cases will arise where it becomes a matter of judgement as to which Order the particular soil is best placed. Similar transitions might occur between shallow Calcarosols and Arenic Rudosols overlying a *layer* of *calcrete* or limestone. Again, *calcareous* Arenic Rudosols will occur where recent aeolian *calcareous* material has been deposited.

In landscapes dominated by wind-blown *calcareous* material it may be difficult to determine if the carbonates are of pedogenic origin. Deep *calcareous* sands, which commonly occur in this situation, are now included in the Arenosols

[3] The carbonate is a result of soil forming processes, in contrast to fragments of calcareous rock such as limestone. See also *calcrete*.



Distribution of Calcarosols in Australia.

Order. Soils with minimal soil development and dominated by coarse fragments of shells or other aquatic animals are included in Shelly Rudosols.

In dune landscapes, where these soils frequently occur, it is common to find evidence of post-European settlement *deflation* and layering of *soil profile*s caused by wind erosion and consequent deposition. Unless the surface depositional material is 0.3 m or more thick, it is ignored in the classification and treated as a phase. (See 'What do we classify?')

Suborders

••• Soils that dominantly consist of gypsum crystals that are sand-sized or finer. **Hypergypsic [FJ]**

••• Soils that are *calcareous* throughout. The upper 0.1 m of the *solum* consists of dominantly *fine earth* carbonate (visual estimate) and/or contains more than 40% (by analysis) of *fine earth* carbonate. **Carbonatic [JT]**

••• Soils in which the carbonate is evident only as a slight to moderate effervescence (1 M HCl), and/or contain less than 2% *fine earth* carbonate, and have less than 20% *hard* carbonate nodules or concretions. **Hypocalcic [CV]**

••• Soils with a *calcareous horizon* containing more than 50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. **Lithocalcic [DA]**

- ••• Soils with a *calcareous horizon* containing 20–50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. Supracalcic [FB]
- ••• Soils with a *calcareous horizon* containing more than 20% of mainly soft, finely divided carbonate, and 0–20% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions, and/or carbonate-coated *gravel*. Hypercalcic [CQ]
- ••• Other soils with a *calcareous horizon*. (See *carbonate classes* in glossary.) Calcic [BD]

Comment

The *calcareous* classes above approximately correspond to those of Wetherby and Oades (1975) as follows: Hypocalcic – Class IV, Lithocalcic – Class III B and IIIC, Supracalcic – Class III B, Hypercalcic – Class III A, Calcic – Class 1 and IIIA.

In the Lithocalcic and Supracalcic classes the coarse fragments may be >0.2 m in size and soft carbonate may or may not be present.

The Carbonatic Suborder partially replaces the former Shelly Suborder which is now restricted to soils dominated by shell fragments in Rudosols. The Carbonatic soils are typically highly *calcareous* and dominated by *fine earth* carbonates throughout the profile.

Of the profiles classified, the Calcic and Hypercalcic Suborders are the most common.

Great Groups

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

Hypergypsic Calcarosols

Insufficient information is available to subdivide these soils further.

Other Calcarosols

Not all Great Groups will be relevant for every Suborder, for example, Rendic will be required only for the Hypercalcic Suborder.

- •• Soils that directly overlie a *red-brown hardpan*. Duric [BJ]
- •• Soils that directly overlie a *calcrete pan*. Petrocalcic [DZ]
- •• Soils in which the *A horizon* directly overlies a Bk horizon consisting almost entirely of soft carbonate (>80%). Rendic [EE]
- •• Soils with an *argic horizon* within the *B horizon*. Argic [AP]

- •• Soils in which the *major part* of the *B horizon* has a grade of structure that is stronger than weak. Pedal [DY]
- •• Soils that directly overlie *hard* rock. Lithic [CZ]
- •• Soils that directly overlie partially weathered or decomposed rock or saprolite. Paralithic [DU]
- •• Soils that directly overlie *marl*. Marly [DD]
- •• Other soils that directly overlie *unconsolidated mineral materials*. Regolithic [GF]

Subgroups

The following Subgroups will not be applicable to all Great Groups of each Suborder, and not all Subgroups are mutually exclusive. The Supravescent and Hypervescent classes are not required for the Carbonatic Suborder. The Supravescent and Hypervescent classes may also be Epihypersodic or Endohypersodic. However, the high content or absence of carbonate in the upper 0.1 m is thought to have more influence on land use than high sodicity. Several soils have been recorded as having a *conspicuously bleached A2 horizon*. In many cases, however, this may be a reflection of high contents of *fine earth* carbonate, hence this feature has not been used as a class differentia.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- Soils with a *melanic horizon* overlying a *B horizon* in which at least 0.3 m has *vertic properties*. Melanic-Vertic [DN]
- Other soils with a *melanic horizon*. Melanic [DK]
- Other soils with a *B horizon* in which at least 0.3 m has *vertic properties*. Vertic [EX]
- Soils in which the *B horizon* is strongly *subplastic* and the B or BC horizon contains a *gypsic horizon*. Gypsic-Subplastic [FL]
- Other soils with a strongly *subplastic B horizon*. Subplastic [ET]
- Soils with a *gypsic horizon* within the B or BC horizon. Gypsic [BZ]
- Soils that are not *calcareous* in the A1 or *Ap horizon*, or to a depth of 0.2 m if the *A1 horizon* is only *weakly developed*. Epibasic [IB]
- Soils in which the upper 0.1 m of the *solum* consists of dominantly fine-earth carbonate (visual estimate), and/or contains more than 40% (by analysis) of *fine earth* carbonate. Supravescent [HK]

- Soils in which the upper 0.1 m of the *solum* consists of more than 20% *fine earth* carbonate (visual estimate using a 10 × hand lens), and/or has a strong effervescence with 1 M HCl, and/or contains more than 8%[4] (by analysis) of *fine earth* carbonate. Hypervescent [CP]
- Soils in which at least some subhorizon within the upper 0.5 m of the *solum* has an *ESP* of 15 or greater. Epihypersodic [BR]
- Soils in which an *ESP* of 15 or greater occurs in some subhorizon below 0.5 m. Endohypersodic [BP]
- Other soils. Ceteric [IC]

[4] Based on numerous *fine earth* analyses by Primary Industries, South Australia.

Family Criteria

Use of the term *A horizon* may be inappropriate for some of these soils because of either minimal development due to an arid environment, or common surface *deflation* or accumulation caused by wind. Hence it is thought better to use the term surface soil for texture and to delete the thickness criteria. In general, surface soil in this context will probably be in the range of 0.1–0.2 m in thickness. For the Calcarosols, a criterion is used to indicate the thickness above the upper boundary of the Bk horizon.

Thickness of soil above upper boundary of *Bk horizon* (if present)

Thin	**[A]**	<0.1 m
Moderately thick	**[B]**	0.1–<0.3 m
Thick	**[C]**	0.3–0.6 m
Very thick	**[D]**	>0.6 m

Gravel of the surface and *A1 horizon*

Non-gravelly	**[E]**	<2%
Slightly gravelly	**[F]**	2–<10%
Gravelly	**[G]**	10–<20%
Moderately gravelly	**[H]**	20–50%
Very gravelly	**[I]**	>50%

Surface soil texture

Peaty	**[J]**	Dominated by *organic materials*
Sandy	**[K]**	S-LS-CS (≤10% clay)
Loamy	**[L]**	SL-L (10–20% clay)
Clay loamy	**[M]**	SCL-CL (20–35% clay)
Silty	**[N]**	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	**[O]**	LC-MC-HC (>35% clay)

B horizon maximum texture[5]

Sandy	**[K]**	S-LS-CS (≤10% clay)
Loamy	**[L]**	SL-L (10–20% clay)
Clay loamy	**[M]**	SCL-CL (20–35% clay)
Silty	**[N]**	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	**[O]**	LC-MC-HC (>35% clay)

Soil depth

Very shallow	**[T]**	<0.25 m
Shallow	**[U]**	0.25–<0.5 m
Moderately deep	**[V]**	0.5–<1.0 m
Deep	**[W]**	1.0–<1.5 m

[5] This refers to the most clayey field texture category.

Very deep	[**X**]	1.5–5 m
Giant	[**Y**]	>5 m

Water repellence of surface soil

Non water repellent	[**NR**]	Water absorbed in 10 seconds or less
Water repellent	[**WR**]	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	[**SR**]	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

Chromosols [CH]

[Pronounced Chrome-oh-sols]

Concept

Soils with strong texture contrast between *A horizons* and *B horizons*. The latter are not *strongly acid* and are not *sodic*. The soils of this Order are among the most widespread soils used for agriculture in Australia, particularly those with red subsoils.

Definition

Soils other than Hydrosols with a *clear or abrupt textural B horizon* and in which the *major part* of the upper 0.2 m of the B2t horizon (or the *major part* of the entire B2t horizon if it is <0.2 m thick) is not *sodic* and not *strongly acid*. Soils with strongly *subplastic* upper *B2t horizons* are also included even if they are *sodic*.

Comment

In the case of those soils with strongly *subplastic B horizons*, care needs to be taken to ensure if they qualify for the *clear or abrupt textural B horizon*. As far as is presently known, such soils appear to be largely confined to the Riverine Plain of south-eastern Australia.

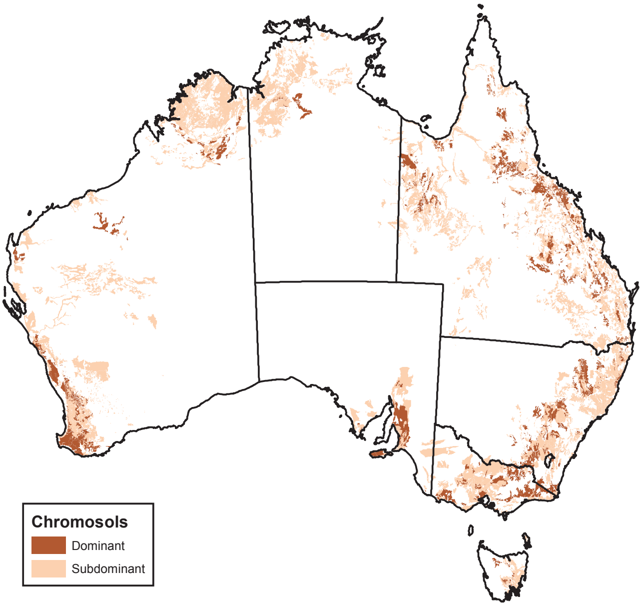
Suborders

The dominant colour class in the *major part* of the upper 0.2 m of the B2t horizon (or the *major part* of the entire B2t horizon if it is <0.2 m thick) is:

••• Red. Red [AA]
••• Brown. Brown [AB]
••• Yellow. Yellow [AC]
••• Grey. Grey [AD]
••• Black. Black [AE]

Comment

The Red and Brown Suborders account for the majority of the profiles classified.



Distribution of Chromosols in Australia.

Great Groups

These will vary somewhat among the various colour class Suborders, but it is likely that the subdivision given below will apply to most.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

•• Soils with a *red-brown hardpan* either within or directly underlying the *B horizon*. **Duric [BJ]**

•• Soils with a *petroferric horizon* within the *solum*. **Petroferric [EA]**

•• Soils with a *B horizon* that is not *calcareous* and which directly overlies a *calcrete pan*. **Petrocalcic [DZ]**

•• Soils in which the upper 0.2 m of the B2t horizon (or the B2t horizon if it is <0.2 m thick) has a strong blocky or polyhedral structure in which average ped size is usually in the range of 5–20 mm. There is very weak adhesion between peds (when dry it is very easy to insert a spade into the upper B2t horizon). Salt contents are usually high, resulting in weak dry strength and a bulk density of ~1.3 t m^{-3} or less. In some soils the B2t horizon may be weakly *subplastic*. A common feature (but not diagnostic) of the overlying *A horizons* is the presence of a band of *vesicular pores* near the surface or on the underside of any surface flake. **Pedaric [BK]**

- Soils in which the *major part* of the B2t horizon is strongly *subplastic*.
  Subplastic [ET]
- Soils with an exchangeable Ca/Mg ratio of less than 0.1 in the *major part* of the B2t horizon. **Magnesic [DB]**
- Soils in which the *major part* of the B2t horizon is *dystrophic*.
  Dystrophic [AF]
- Soils in which the *major part* of the B2t horizon is *mesotrophic*.
  Mesotrophic [AG]
- Soils in which the *major part* of the B2t horizon is *eutrophic* but the *B* and *BC horizons* are not *calcareous*. **Eutrophic [AH]**
- Soils in which the carbonate is evident only as a slight to moderate effervescence (1 M HCl), and/or contain less than 2% soft finely divided carbonate, and have less than 20% *hard* carbonate nodules or concretions.
  Hypocalcic [CV]
- Soils with a *calcareous horizon* containing more than 50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. **Lithocalcic [DA]**
- Soils with a *calcareous horizon* containing 20–50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. **Supracalcic [FB]**
- Soils with a *calcareous horizon* containing more than 20% of mainly soft, finely divided carbonate, and 0–20% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions, and/or carbonate-coated *gravel*.
  Hypercalcic [CQ]
- Other soils with a *calcareous horizon*. (See *carbonate classes* in glossary.)
  Calcic [BD]

Comment

The *calcareous* classes above approximately correspond to those of Wetherby and Oades (1975) as follows: Hypocalcic – Class IV, Lithocalcic – Class III B and IIIC, Supracalcic – Class III B, Hypercalcic – Class III A, Calcic – Class 1 and IIIA. In the Lithocalcic and Supracalcic classes the coarse fragments may be >0.2 m in size and soft carbonate may or may not be present.

Of the profiles classified during database testing, the Calcic class was found to be most common in soils with a *calcareous horizon*. However, a large proportion of the Chromosol Great Groups classified were *Eutrophic*. The Duric and Pedaric soils are virtually confined to the arid zone, the former being particularly widespread in Western Australia and the latter in western Queensland and New South Wales, and in South Australia.

Subgroups

The Subgroups listed below may not all be relevant for every Great Group of every Suborder.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- Soils with a *peaty horizon*. Peaty [DW]
- Soils with a *humose horizon* and a *conspicuously bleached A2 horizon*. Humose-Bleached [EY]
- Soils with a *humose horizon* and the *major part* of the B2t horizon is mottled. Humose-Mottled [CM]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon* and the *major part* of the B2t horizon is mottled. Melacic-Mottled [DI]
- Other soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon* and a *B horizon* in which at least 0.3 m has *vertic properties*. Melanic-Vertic [DN]
- Soils with a *melanic horizon* and the *major part* of the B2t horizon is mottled. Melanic-Mottled [DM]
- Other soils with a *melanic horizon*. Melanic [DK]
- Soils with a *conspicuously bleached A2 horizon* overlying a *B horizon* in which at least 0.3 m has *vertic properties*. Bleached-Vertic [BB]
- Other soils with a *B horizon* in which at least 0.3 m has *vertic properties*. Vertic [EX]
- Soils with a *gypsic horizon* within the B or BC horizon. Gypsic [BZ]
- Soils with a *ferric horizon* within the *solum*, and at least the lower part of the *B horizon* is *sodic*. Ferric-Sodic [HC]
- Soils with a *conspicuously bleached A2 horizon* and a *ferric horizon* within the *solum*. Bleached-Ferric [AV]
- Other soils with a *ferric horizon* within the *solum*. Ferric [BU]
- Soils with a *conspicuously bleached A2 horizon* and a *manganic horizon* within the *solum*. Bleached-Manganic [AY]
- Other soils with a *manganic horizon* within the *solum*. Manganic [DC]
- Soils with *fine earth* effervescence (1 M HCl) throughout the *solum*. Effervescent [IE]

- Soils with a *conspicuously bleached A2 horizon* and a *B horizon* in which at least the lower part is *sodic*. **Bleached-Sodic [BA]**
- Soils in which the *major part* of the B2t horizon is mottled, and at least the lower part of the *B horizon* is *sodic*. **Mottled-Sodic [HB]**
- Other soils with a *B horizon* in which at least the lower part is *sodic*. **Sodic [EO]**
- Soils with a *conspicuously bleached A2 horizon* and the *major part* of the B2t horizon is mottled. **Bleached-Mottled [AZ]**
- Other soils with a *conspicuously bleached A2 horizon*. **Bleached [AT]**
- Soils with a *reticulate horizon* below the B2t horizon. **Reticulate [EF]**
- Other soils in which the *major part* of the B2t horizon is mottled. **Mottled [DQ]**
- Other soils in which the *major part* of the B2t horizon is whole coloured. **Haplic [CD]**

Comment

A large proportion of the profiles classified so far have a Haplic Subgroup. This would suggest that the class may need to be further subdivided, but it is difficult to find suitable criteria to base this on. The presence of a pale (unbleached) *A2 horizon* could be used, but the significance of this is uncertain. A subdivision could be made between soils with clear or abrupt textural changes if this was thought to be of importance. Similarly, a distinction between structured and massive *B2t horizons* could be made.

Possible changes such as these can easily be introduced if evidence is produced to justify their use.

Family Criteria

A horizon thickness plus the thickness of organic horizons (O2, P1 or P2) if present

Thin	[A]	<0.1 m
Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

Gravel of the surface and *A1 horizon*

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

A1 horizon texture or texture of organic horizons (O2, P1 or P2) if present

Peaty	[J]	Dominated by *organic materials*
Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)

B horizon maximum texture[6]

Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

Soil depth

Very shallow	[T]	<0.25 m
Shallow	[U]	0.25–<0.5 m
Moderately deep	[V]	0.5–<1.0 m
Deep	[W]	1.0–<1.5 m
Very deep	[X]	1.5–5 m
Giant	[Y]	>5 m

Water repellence of surface soil

Non water repellent	[NR]	Water absorbed in 10 seconds or less
Water repellent	[WR]	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	[SR]	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

[6] This refers to the most clayey field texture category.

Dermosols [DE]

[Pronounced Derm-oh-sols]

Concept

Soils with structured *B2 horizons* and lacking a strong texture contrast between the A and *B horizons*. Although there is some diversity within the Order, it brings together a range of soils with some important properties in common.

Definition

Soils other than Vertosols, Hydrosols, Calcarosols and Ferrosols that:

1. Have *B2 horizons* that have *grade of pedality* greater than weak[7] throughout the *major part* of the horizon, and
2. Do not have a *clear or abrupt textural B horizon*.

Comment

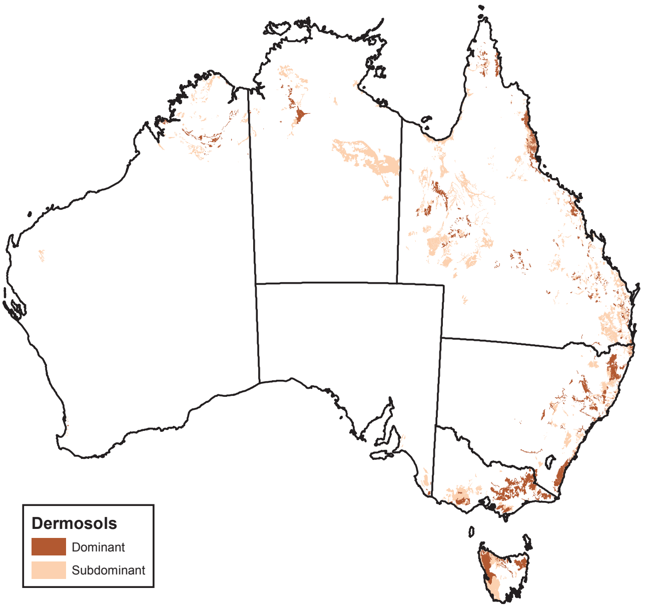
Some clayey soils in the arid zone which are relatively high in salt tend to have strong, fine blocky structure. It may be difficult to decide if they are Vertosols or Dermosols because of an apparent lack of cracking and *slickensides* or *lenticular peds*. The use of shrinkage measurements such as those discussed under *vertic properties* will help to resolve this situation.

Suborders

The dominant colour class in the *major part* of the upper 0.5 m of the *B2 horizon* (or the *major part* of the entire *B2 horizon* if it is <0.5 m thick) is:

••• Red. Red [AA]
••• Brown. Brown [AB]
••• Yellow. Yellow [AC]
••• Grey. Grey [AD]
••• Black. Black [AE]

[7] It is common experience that pedologists are inclined to use the phrase ‘weak to moderate’ when they are in doubt as to the grade of structure. If such a designation is used it will result in the soil being classed as a Dermosol.



Distribution of Dermosols in Australia.

Comment

The upper 0.5 m of the *B2 horizon* is used as the diagnostic section for colour in Dermosols, Ferrosols and Kandosols because of the often indistinct *A–B horizon* boundaries in these soils compared with those in Chromosols, Kurosols and Sodosols.

Great Groups

It is thought that the Great Group classes listed below will be appropriate for most of the various colour Suborders, although yellow and grey forms are relatively uncommon.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- •• Soils with a *red-brown hardpan* either within or directly underlying the *B horizon*. **Duric [BJ]**
- •• Soils with a *B horizon* either containing or directly underlain by *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. **Petroferric [EA]**
- •• Soils with a *B horizon* that is not *calcareous* and which directly overlies a *calcrete pan*. **Petrocalcic [DZ]**
- •• Soils in which the upper 0.2 m of the *B2 horizon* (or the *B2 horizon* if it is <0.2 m thick) has a strong blocky or polyhedral structure in which average

ped size is usually in the range of 5–20 mm. There is very weak adhesion between peds (when dry it is very easy to insert a spade into the upper *B2 horizon*). Salt contents are usually high, resulting in weak dry strength and a bulk density of ~1.3 t m^{-3} less. In some soils the *B2 horizons* may be weakly *subplastic*. A common feature (but not diagnostic) of the overlying *A horizons* is the presence of a band of *vesicular pores* near the surface or on the underside of any surface flake. Pedaric [BK]

- •• Soils in which the *major part* of the *B2 horizon* is strongly *subplastic*. Subplastic [ET]
- •• Soils with an exchangeable Ca/Mg ratio of less than 0.1 in the *major part* of the *B2 horizon*. Magnesic [DB]
- •• Soils in which the *major part* of the *B2 horizon* is *dystrophic*. Dystrophic [AF]
- •• Soils in which the *major part* of the *B2 horizon* is *mesotrophic*. Mesotrophic [AG]
- •• Soils in which the *major part* of the *B2 horizon* is *eutrophic* but the *B* and *BC horizons* are not *calcareous*. Eutrophic [AH]
- •• Soils in which the carbonate is evident only as a slight to moderate effervescence (1 M HCl), and/or contain less than 2% soft finely divided carbonate, and have less than 20% *hard* carbonate nodules or concretions. Hypocalcic [CV]
- •• Soils with a *calcareous horizon* containing more than 50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. Lithocalcic [DA]
- •• Soils with a *calcareous horizon* containing 20–50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. Supracalcic [FB]
- •• Soils with a *calcareous horizon* containing more than 20% of mainly soft, finely divided carbonate, and 0–20% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions, and/or carbonate-coated *gravel*. Hypercalcic [CQ]
- •• Other soils with a *calcareous horizon*. (See *carbonate classes* in glossary.) Calcic [BD]

Comment

The *calcareous* classes above approximately correspond to those of Wetherby and Oades (1975) as follows: Hypocalcic – Class IV, Lithocalcic – Class III B and III C, Supracalcic – Class III B, Hypercalcic – Class III A, Calcic – Class I and IIIA. In the Lithocalcic and Supracalcic classes the coarse fragments may be >0.2 m in size and soft carbonate may or may not be present.

Of the profiles classified, the *Eutrophic* class was the most common Great Group. The Duric and Pedaric soils are virtually confined to the arid zone, the former being particularly widespread in Western Australia and the latter in western Queensland and New South Wales, and in South Australia.

Subgroups

It is thought that the following Subgroups will cater for most situations, although obviously some will not be relevant for particular Great Groups.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- Soils with a *humose horizon* and the *major part* of the *B2 horizon* is mottled. Humose-Mottled [CM]
- Soils with a *humose horizon* and the *major part* of the *B2 horizon* is *strongly acid*. Humose-Acidic [GY]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon* and a *reticulate horizon* that occurs below the *B2 horizon*. Melacic-Reticulate [GC]
- Soils with a *melacic horizon* and the *major part* of the *B2 horizon* is mottled. Melacic-Mottled [DI]
- Other soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon* and a *B horizon* in which at least 0.3 m has *vertic properties*. Melanic-Vertic [DN]
- Soils with a *melanic horizon* and the *major part* of the *B2 horizon* is mottled. Melanic-Mottled [DM]
- Soils with a *melanic horizon* and the *major part* of the *B2 horizon* is *strongly acid*. Melanic-Acidic [FV]
- Soils with a *melanic horizon* and a *B horizon* in which at least the lower part is *sodic*. Melanic-Sodic [HA]
- Other soils with a *melanic horizon*. Melanic [DK]
- Soils with a *conspicuously bleached A2 horizon* and a *B horizon* in which at least 0.3 m has *vertic properties*. Bleached-Vertic [BB]
- Other soils with a *B horizon* in which at least 0.3 m has *vertic properties*. Vertic [EX]
- Soils with a *gypsic horizon* within the B or BC horizon. Gypsic [BZ]
- Soils with a *ferric horizon* within the *solum* and a *B2 horizon* in which the *major part* is *strongly acid*. Ferric-Acidic [GW]

- Soils with a *ferric horizon* within the *solum* and a *B horizon* in which at least the lower part is *sodic*. Ferric-Sodic [HC]
- Soils with a *conspicuously bleached A2 horizon* and a *ferric horizon* within the *solum*. Bleached-Ferric [AV]
- Other soils with a *ferric horizon* within the *solum*. Ferric [BU]
- Soils with a *manganic horizon* within the *solum* and a *B2 horizon* in which the *major part* is *strongly acid*. Manganic-Acidic [GX]
- Soils with a *conspicuously bleached A2 horizon* and a *manganic horizon* within the *solum*. Bleached-Manganic [AY]
- Other soils with a *manganic horizon* within the *solum*. Manganic [DC]
- Soils in which the *major part* of the *B2 horizon* is *strongly acid* and at least the lower part is *sodic*. Acidic-Sodic [HO]
- Soils with a *conspicuously bleached A2 horizon* and a *B2 horizon* in which the *major part* is *strongly acid*. Bleached-Acidic [AU]
- Soils in which the *major part* of the *B2 horizon* is *strongly acid* and mottled. Acidic-Mottled [AJ]
- Other soils with a *B2 horizon* in which the *major part* is *strongly acid*. Acidic [AI]
- Soils with a *conspicuously bleached A2 horizon* and a *B horizon* in which at least the lower part is *sodic*. Bleached-Sodic [BA]
- Soils in which the *major part* of the *B2 horizon* is mottled and at least the lower part of the *B horizon* is *sodic*. Mottled-Sodic [HB]
- Other soils with a *B horizon* in which at least the lower part is *sodic*. Sodic [EO]
- Soils with a *conspicuously bleached A2 horizon* and the *major part* of the *B2 horizon* is mottled. Bleached-Mottled [AZ]
- Other soils with a *conspicuously bleached A2 horizon*. Bleached [AT]
- Soils with a *reticulate horizon* below the *B2 horizon*. Reticulate [EF]
- Soils in which the *major part* of the *B2 horizon* is mottled. Mottled [DQ]
- Soils in which the *major part* of the *B2 horizon* is whole coloured. Haplic [CD]

Comment

In some *Dystrophic* Dermosols there can be a problem with the definition of *Sodic* Subgroups because of their low *base status* (see *ESP*). No provision is made for Acidic Subgroups for soils with *melacic horizons* as these are most likely to always have acid *B2 horizons*. Similarly, Acidic Subgroups are unlikely to be required for the *Dystrophic* Great Groups as most such soils will be acid, whereas the *Eutrophic* Great Groups are unlikely to be acid. Several classes are not mutually exclusive, thus many Vertic Subgroups are probably also *Sodic* or Bleached-Sodic. It is not possible to cater for all such combinations. Of the profiles classified to date many are Haplic, indicating a possible need for further subdivision.

Family Criteria

A1 horizon thickness plus the thickness of organic horizons (O2, P1 or P2) if present

Thin	[A]	<0.1 m
Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

Gravel of the surface and *A1 horizon*

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

A1 horizon texture or texture of organic horizons (O2, P1 or P2) if present

Peaty	[J]	Dominated by *organic materials*
Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

B horizon maximum texture[8]

Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

Soil depth

Very shallow	[T]	<0.25 m
Shallow	[U]	0.25–<0.5 m
Moderately deep	[V]	0.5–<1.0 m
Deep	[W]	1.0–<1.5 m
Very deep	[X]	1.5–5 m
Giant	[Y]	>5 m

[8] This refers to the most clayey field texture category.

Ferrosols [FE]

[Pronounced Ferro-sols]

Concept

Soils with *B2 horizons* that are high in *free iron oxide* and lacking a strong texture contrast between the A and *B horizons*.

Definition

Soils other than Vertosols, Hydrosols, and Calcarosols that:

1. Have *B2 horizons* in which the *major part* has a *free iron oxide* content greater than 5% Fe in the *fine earth* fraction (<2 mm), and
2. Do not have a *clear or abrupt textural B horizon* or a *B2 horizon* in which at least 0.3 m has *vertic properties*.

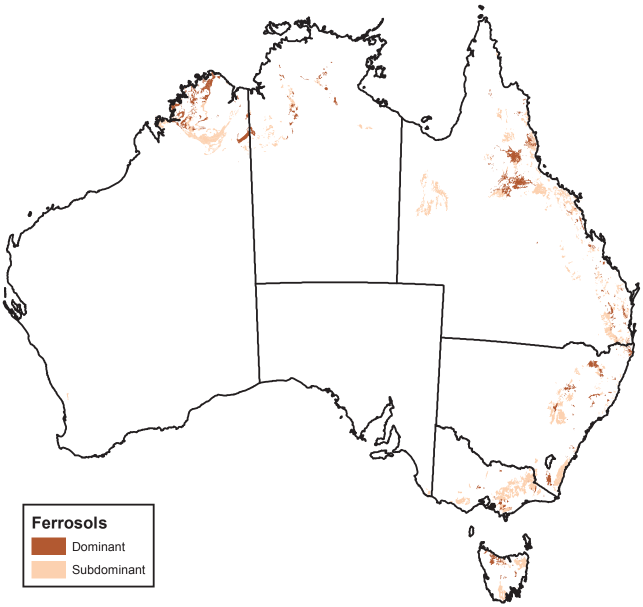
Comment

These soils are almost entirely formed on either mafic or ultramafic igneous rocks, their metamorphic equivalents, or alluvium derived therefrom. Although these soils do not occupy large areas in Australia, they are widely recognised and often intensively used because of their favourable physical properties. The most common forms have *B2 horizons* with a strong *grade of pedality*; such *horizons* typically have polyhedral compound peds up to 10–15 mm, usually with smooth and often shiny faces, which break down readily to primary peds ~5 mm or less in size. However, forms also occur with a very fine granular structure which may appear massive in place. *Horizons* are usually high in clay and *subplastic*.

Suborders

The dominant colour class in the *major part* of the upper 0.5 m of the *B2 horizon* (or the *major part* of the entire *B2 horizon* if it is <0.5 m thick) is:

••• Red. Red [AA]
••• Brown. Brown [AB]
••• Yellow. Yellow [AC]
••• Grey. Grey [AD]
••• Black. Black [AE]



Distribution of Ferrosols in Australia.

Great Groups

It is thought that the Great Group classes listed below will be appropriate for each colour Suborder. Red and Brown are by far the most common *colour classes*. Of the Great Groups listed below, the *Calcareous* and Magnesic classes are relatively uncommon.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- •• Soils that are underlain within 0.5 m of the surface by a *calcrete pan*; *hard* unweathered rock or other *hard* materials; or partially weathered or decomposed rock or saprolite. Leptic [CY]
- •• Soils with an exchangeable Ca/Mg ratio of less than 0.1 in the *major part* of the *B2 horizon*. Magnesic [DB]
- •• Soils in which the *major part* of the *B2 horizon* is *dystrophic*. Dystrophic [AF]
- •• Soils in which the *major part* of the *B2 horizon* is *mesotrophic*. Mesotrophic [AG]
- •• Soils in which the *major part* of the *B2 horizon* is *eutrophic* but the *B* and *BC horizons* are not *calcareous*. Eutrophic [AH]
- •• Soils in which at least some part of the B or the BC horizon is *calcareous*. Calcareous [BC]

Subgroups

It is thought that the following Subgroups will cater for most situations, although obviously some will not be relevant for particular Great Groups.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- Soils with an *A horizon* having a very fine granular structure (<2 mm) and a dry consistence strength that is weak to very weak. The horizon usually has a low bulk density and may be water repellent. Snuffy [EN]
- Soils with a *humose horizon* and the *major part* of the *B2 horizon* is *strongly acid*. Humose-Acidic [GY]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon* and the *major part* of the *B2 horizon* is mottled. Melanic-Mottled [DM]
- Soils with a *melanic horizon* and the *major part* of the *B2 horizon* is *strongly acid*. Melanic-Acidic [FV]
- Other soils with a *melanic horizon*. Melanic [DK]
- Soils with a *ferric horizon* within the *solum* and a *B2 horizon* in which the *major part* is *strongly acid*. Ferric-Acidic [GW]
- Other soils with a *ferric horizon* within the *solum*. Ferric [BU]
- Soils with a *manganic horizon* within the *solum*. Manganic [DC]
- Soils with a *B2 horizon* in which the *major part* is *strongly acid*. Acidic [AI]
- Soils with a *B2 horizon* in which at least the lower part is *sodic*. Sodic [EO]
- Soils in which the *major part* of the *B2 horizon* is mottled. Mottled [DQ]
- Soils in which the *major part* of the *B2 horizon* is whole coloured. Haplic [CD]

Comment

The Haplic Subgroup is the most common in the Ferrosols classified to date, followed by Acidic with the remaining Subgroups fairly evenly distributed. All Haplic soils have been further examined, but apart from possibly using structure there seem to be few other differentiae that could be used for further subdivision.

Family Criteria

A1 horizon thickness plus the thickness of organic horizons (O2, P1 or P2) if present

Thin	[A]	<0.1 m
Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

Gravel of the surface and *A1 horizon*

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

A1 horizon texture or texture of organic horizons (O2, P1 or P2) if present

Peaty	[J]	Dominated by *organic materials*
Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

B horizon maximum texture[9]

Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

Soil depth

Very shallow	[T]	<0.25 m
Shallow	[U]	0.25–<0.5 m
Moderately deep	[V]	0.5–<1.0 m
Deep	[W]	1.0–<1.5 m
Very deep	[X]	1.5–5 m
Giant	[Y]	>5 m

Water repellence of surface soil

Non water repellent	[NR]	Water absorbed in 10 seconds or less
Water repellent	[WR]	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	[SR]	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

[9] This refers to the most clayey field texture category.

Hydrosols [HY]

[Pronounced Hi-dro-sols]

Concept

This Order is designed to accommodate a range of seasonally or permanently wet soils and thus there is some diversity within the Order. The key criterion is saturation of the *major part* of the *soil profile* for prolonged periods (2–3 months) in most years. Some Hydrosols are permanently submerged. The soils may or may not experience reducing conditions for all or part of the period of saturation, and thus manifestations of reduction and oxidation such as *gley colours* and ochrous mottles may or may not be present.

Saturation by a water table may not necessarily be caused by low soil permeability. Often site drainage will be the most important factor, while in other well known cases tidal influence is dominant. The relevant *Field Handbook* drainage classes are very poorly and poorly drained.

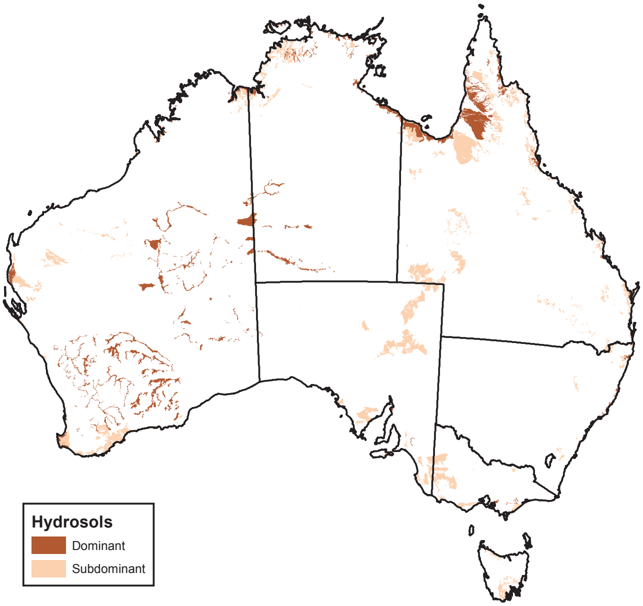
Several major classes of soils are excluded because it is considered their other profile characteristics are of greater significance than wetness. These are the Organosols, Podosols and Vertosols. Although some Hydrosols are dominated by *organic materials* (see Intertidal Hydrosols below), it is thought that because of their unique nature (i.e. largely consisting of mangrove debris that is regularly inundated by saline tidal waters), it is more appropriate to classify them as an organic form of Hydrosols rather than as a class of Organosols that occur in a mangrove environment.

Definition

Soils other than Organosols, Podosols and Vertosols in which the *major part* of the *soil profile* is saturated for at least 2–3 months in most years.

Comment

The approach taken in this concept of ‘wet’ soils differs from more traditional usage in that reducing conditions are not emphasised. The rationale for the present approach is based on the assumption that saturation affects soil properties irrespective of whether or not reducing conditions are present. Obvious examples are those relating to certain physical and engineering properties, which result in limitations to the use of a soil (e.g. trafficability).



Distribution of Hydrosols in Australia.

A further reason for not making reducing conditions mandatory is the well known difficulty in identifying such conditions, which are often of a temporal nature and sporadic in spatial distribution. It is widely recognised that the traditional use of *gley colours* and particular kinds of mottling are not universally indicative of a saturated condition or its duration. In particular, mottles or other segregations can be relict. Another problem in identification of reducing conditions, is the experience that various indicator dyes such as α,α-dipyridyl (Childs and Clayden 1986) may be unreliable.

It will also be apparent that the concept adopted for Hydrosols will normally exclude the pseudo (or surface water) gley class commonly distinguished in several European classification schemes. These soils have a perched water table usually caused by a slowly permeable horizon or *layer* within the *soil profile*.

A difficult question arises as to how artificially drained soils are best treated. In many cases drainage will merely lower the water table to depths which permit the successful growth of particular plants. Such depths may still be relatively shallow (e.g. 0.5–1.0 m), and capillary rise may result in wet soil conditions to variable heights above the new water table. Additionally, the topographic situation and/or the climatic environment may mean that drainage merely reduces the period of saturation. If drainage is such that saturation no longer occurs for appropriate periods in the relevant parts of the profile, the soil can strictly no longer be considered a Hydrosol. Possibly a 'drained' phase may be appropriate in some such circumstances.

In the case of irrigated soils, the main example is when more or less permanent flood irrigation is employed to grow rice. This would be expected to change, for example, a Chromosol to a Chromosolic Hydrosol. It should be noted that the definition of the Order is deliberately somewhat equivocal in that the duration and frequency of saturation of a precise section of the profile are not specifically defined. Lack of water table data is one reason, but it is also thought that a degree of flexibility is required for the definition. It is recognised that the extent of soil wetness can seldom be assessed by a single inspection of a particular site. However, experience has shown that judicious questioning of people with local knowledge, together with the soil scientist's assessment of soil and site drainage and climatic environment, can usually achieve a satisfactory resolution of the problem.

Suborders

- ••• Soils of tidal estuaries, bays and river deltas that experience permanent inundation between *Mean Low Water Springs* (MLWS) and 2.5 m below *MLWS*. **Subtidal [IU]**
- ••• Soils of inland water bodies that are located between the water surface and 2.5 m below the surface. **Subaqueous [IV]**
- ••• Soils of intertidal flats (often colonised by mangroves) that experience regular saline tidal inundation of mostly high frequency. **Intertidal [CW]**
- ••• Soils of supratidal flats (normally bare of vegetation except for halophytes such as samphires), often salt-encrusted. Tidal inundation is infrequent (spring tides) but a saline water table is present at shallow depths. **Supratidal [EW]**
- ••• Soils of the extratidal zone (usually supporting grassland). Tidal inundation is infrequent and achieved only by exceptional storm or cyclonic tides (above high spring tides). Freshwater inundation is seasonally common. **Extratidal [BT]**
- ••• Soils of the saline playa lakes (including coastal salinas and continental playas) which are usually bare and when dry are frequently halite- or gypsum-encrusted, or with a sparse cover of halophytes such as samphires. The continental playas are infrequently inundated with fresh water, but a shallow saline groundwater table is usually present in all types throughout the year, mostly within 0.5 m of the surface. **Hypersalic [CS]**
- ••• Salinised soils caused by a rising saline water table or by saline seepage resulting from near-surface lateral movement (through flow) of water and salt from higher landscape positions. Such areas may be bare and salt-encrusted, often have a soft fluffy surface, and may or may not have a sparse cover of halophytic plants. Water table conductivity will usually be

in the range of 2–50 dS m^{-1}; soil salinity may vary widely due to capillary concentration at or near the surface, and subsequent leaching of salt by seasonal precipitation. **Salic [EG]**

••• Soils with a seasonal or permanent water table and in which the *major part* of the *soil profile* (or the subsoil if the profile is stratified) is mottled. **Redoxic [ED]**

••• Other soils with a seasonal or permanent water table and in which the *major part* of the *soil profile* (or the subsoil if the profile is stratified) is whole coloured. **Oxyaquic [DT]**

Comment

The features used in the definitions of the first seven Suborders differ from those used elsewhere in the classification in that the classes are essentially based on the frequency of tidal or freshwater inundation and the nature of the soil surface. This is thought to be an appropriate approach as the key feature of Hydrosols is their wetness. The references in parenthesis to vegetation in some definitions are merely indicating accessory properties of the class which may aid identification of what are essentially wetness criteria, for example, the presence of certain mangrove species will normally indicate a regular frequency of tidal wetting. Although it may be difficult to identify the Extratidal Suborder by the low frequency of tidal inundation, there is usually a distinct boundary between this zone and the often bare, salt-encrusted Supratidal zone. This boundary is commonly marked by a low (0.1–0.2 m) 'scarp'. The three tidal-affected Suborders of Intertidal, Supratidal and Extratidal are largely based on data from Cook and Mayo (1977).

For the purposes of soil classification, Hydrosols located within Intermittently Closed and Open Lakes and Lagoons (ICOLLS) are considered to be tidal.

Where inundation at the perimeter of larger water bodies is cyclical as a result of seiches or from variability in rainfall and runoff, it is often difficult to decide if currently submerged soils are either Subaqueous, Redoxic or Oxyaquic. Their classification will depend on conditions at the time of sampling and knowledge of the frequency and duration of any drying on exposure. With some submerged soils, evidence of prior surface soil aeration such as the development of mottles, soil structure or very low *pH* suggests that the soils are not Subaqueous (i.e. subject to permanent saturation). If the period of exposure is insufficient to allow substantial soil aeration and there is no evidence of oxidation and drying, then the soils are considered to be Subaqueous.

In the Salic Suborder the salinisation may or may not be human-induced. Saline water tables may arise as a result of a sequence of wetter-than-average years, or they may result from activities such as a tree clearing and/or unwise irrigation practices. With time it is likely that some of the human-induced saline soils will tend to those of the Hypersalic Suborder, as evidenced in some of the saline valleys of the Western Australian wheat belt. It also follows that a wide range of soils is likely to occur in the Salic Suborder.

In the Redoxic and Oxyaquic Suborders water tables are normally non-saline. However exceptions may occur where these soils are underlain by sulfuric and/or *sulfidic materials*, as described by Walker (1972). It should be noted that the use of mottling as a diagnostic criterion in the former Suborder does not necessarily imply that oxidising and reducing conditions are currently occurring in the soil in most years.

Great Groups

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

Subtidal, Intertidal and Subaqueous Hydrosols

Conventional horizon nomenclature is inapplicable to these soils, hence the use of arbitrary depth limits.

•• Soils in which *sulfuric material* (at least 0.15 m thick) occurs within the upper 1.5 m of the profile. **Sulfuric [EV]**

Note: The Sulfuric Great Group can be replaced by the following Great Group where appropriate evidence is available:

•• Soils in which both *monosulfidic material* and *sulfuric material* (at least 0.15 m thick) occur within the upper 1.5 m of the profile. **Monosulfidic-Sulfuric [IW]**

•• Soils in which *sulfidic materials* occur within the upper 1.5 m of the profile. **Sulfidic [EU]**

Note: The Sulfidic Great Group can be replaced by the following Great Groups where appropriate evidence is available:

•• Soils in which both *monosulfidic material* and *hypersulfidic material* occur within the upper 1.5 m of the profile. **Monohypersulfidic [IX]**

•• Other soils that are dominated by *organic materials* to a depth of 0.5 m and which have *hypersulfidic material* within the upper 1.5 m of the profile. **Histic-Hypersulfidic [IY]**

•• Other soils in which *hypersulfidic material* occurs within the upper 1.5 m of the profile. **Hypersulfidic [IZ]**

•• Soils in which both *monosulfidic material* and *hyposulfidic material* occur within the upper 1.5 m of the profile. **Monohyposulfidic [JA]**

•• Other soils that are dominated by *organic materials* to a depth of 0.5 m and have *hyposulfidic material* within the upper 1.5 m of the profile. **Histic-Hyposulfidic [JB]**

- Other soils with *hyposulfidic material* within the upper 1.5 m of the profile. **Hyposulfidic [JC]**
- Soils that are dominated by *organic materials* to a depth of 0.5 m. **Histic [CF]**
- Soils that are dominated by other organic-rich (non-vegetative) materials such as faunal debris to a depth of 0.5 m. **Faunic [FW]**
- Soils that are dominantly *calcareous* to a depth of 0.5 m. **Epicalcareous [FY]**
- Soils that are dominantly clay-sized to a depth of 0.5 m. **Argillaceous [AQ]**
- Soils that are dominantly silt-sized to a depth of 0.5 m. **Lutaceous [FX]**
- Soils that are dominantly sand-sized to a depth of 0.5 m. **Arenaceous [BV]**

Supratidal Hydrosols

- Soils in which *sulfuric material* (at least 0.15 m thick) occurs within the upper 1.5 m of the profile. **Sulfuric [EV]**

  Note: The Sulfuric Great Group can be replaced by the following Great Group where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *sulfuric material* (at least 0.15 m thick) occur within the upper 1.5 m of the profile. **Monosulfidic-Sulfuric [IW]**
- Soils in which *sulfidic materials* occur within the upper 1.5 m of the profile. **Sulfidic [EU]**

  Note: The Sulfidic Great Group can be replaced by the following Great Groups where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *hypersulfidic material* occur within the upper 1.5 m of the profile. **Monohypersulfidic [IX]**
- Other soils in which *hypersulfidic material* occurs within the upper 1.5 m of the profile. **Hypersulfidic [IZ]**
- Soils in which both *monosulfidic material* and *hyposulfidic material* occur within the upper 1.5 m of the profile. **Monohyposulfidic [JA]**
- Other soils with *hyposulfidic material* within the upper 1.5 m of the profile. **Hyposulfidic [JC]**
- Soils with a *gypsic horizon* within the upper 0.5 m of the profile. **Gypsic [BZ]**
- Soils in which the *major part* of the upper 0.5 m of the profile is *calcareous*. **Epicalcareous [FY]**
- Soils in which the *major part* of the upper 0.5 m of the profile is mottled. **Mottled [DQ]**

- Soils in which the *major part* of the upper 0.5 m of the profile is whole coloured. Haplic [CD]

Hypersalic Hydrosols

- Soils in which *sulfuric material* (at least 0.15 m thick) occurs within the upper 1.5 m of the profile. Sulfuric [EV]

  Note: The Sulfuric Great Group can be replaced by the following Great Group where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *sulfuric material* (at least 0.15 m thick) occur within the upper 1.5 m of the profile. Monosulfidic-Sulfuric [IW]
- Soils in which *sulfidic materials* occur within the upper 1.5 m of the profile. Sulfidic [EU]

  Note: The Sulfidic Great Group can be replaced by the following Great Groups where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *hypersulfidic material* occur within the upper 1.5 m of the profile. Monohypersulfidic [IX]
- Other soils in which *hypersulfidic material* occurs within the upper 1.5 m of the profile. Hypersulfidic [IZ]
- Soils in which both *monosulfidic material* and *hyposulfidic material* occur within the upper 1.5 m of the profile. Monohyposulfidic [JA]
- Other soils with *hyposulfidic material* within the upper 1.5 m of the profile. Hyposulfidic [JC]
- Soils with a *gypsic horizon* within the upper 0.5 m of the profile. Gypsic [BZ]
- Soils in which the *major part* of the upper 0.5 m of the profile consists of materials dominated (>50%) by halite crystals. Halic [CC]
- Soils in which the *major part* of the upper 0.5 m of the profile is *calcareous*. Epicalcareous [FY]
- Soils in which the *major part* of the upper 0.5 m of the profile is mottled. Mottled [DQ]
- Soils in which the *major part* of the upper 0.5 m of the profile is whole coloured. Haplic [CD]

Extratidal and Salic Hydrosols

High salt contents usually tend to obliterate the original morphology, but where this can still be identified, Great Groups may be established on this basis.

- Soils in which *sulfuric material* (at least 0.15 m thick) occurs within the upper 1.5 m of the profile. Sulfuric [EV]

  Note: The Sulfuric Great Group can be replaced by the following Great Group where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *sulfuric material* (at least 0.15 m thick) occur within the upper 1.5 m of the profile. Monosulfidic-Sulfuric [IW]

- Soils in which *sulfidic materials* occur within the upper 1.5 m of the profile. Sulfidic [EU]

  Note: The Sulfidic Great Group can be replaced by the following Great Groups where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *hypersulfidic material* occur within the upper 1.5 m of the profile. Monohypersulfidic [IX]

- Other soils in which *hypersulfidic material* occurs within the upper 1.5 m of the profile. Hypersulfidic [IZ]

- Soils in which both *monosulfidic material* and *hyposulfidic material* occur within the upper 1.5 m of the profile. Monohyposulfidic [JA]

- Other soils with *hyposulfidic material* within the upper 1.5 m of the profile. Hyposulfidic [JC]

- Soils with a *petroferric horizon* within the *soil profile*. Petroferric [EA]

- Soils that are *calcareous* throughout the *soil profile*, or at least below the *A1 horizon* or to a depth of 0.2 m if the *A1 horizon* is only *weakly developed*, and do not have a *clear or abrupt textural B horizon*. Calcarosolic [CB]

- Soils with a *clear or abrupt textural B horizon* and the *major part* of the upper 0.2 m of the *B2 horizon* is *strongly acid*. Kurosolic [CX]

- Soils with a *clear or abrupt textural B horizon* that is *sodic* and not *strongly acid* in the *major part* of the upper 0.2 m of the *B2 horizon*. Sodosolic [EQ]

- Other soils with a *clear or abrupt textural B horizon* and the pH_w in the *major part* of the upper 0.2 m of the *B2 horizon* is not *strongly acid*. Chromosolic [BG]

- Soils with structured *B2 horizons* and which apart from wetness fulfil the requirements for Dermosols. Dermosolic [FQ]

- Other soils with *B2 horizons* and which apart from wetness fulfil the requirements for Kandosols. Kandosolic [FR]

- Soils which apart from wetness fulfil the requirements for Arenosols. Arenosolic [JM]

- Soils which apart from wetness fulfil the requirements for Tenosols.
Tenosolic [GT]
- Soils which apart from wetness fulfil the requirements for Rudosols.
Rudosolic [GR]

Redoxic and Oxyaquic Hydrosols

The following Great Groups will not all be relevant for each of these two Suborders. For example, the Rudosolic Great Group will not be required for the Redoxic Suborder.

- Soils in which *sulfuric material* (at least 0.15 m thick) occurs within the upper 1.5 m of the profile. Sulfuric [EV]

  Note: The Sulfuric Great Group can be replaced by the following Great Group where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *sulfuric material* (at least 0.15 m thick) occur within the upper 1.5 m of the profile.
Monosulfidic-Sulfuric [IW]
- Soils in which *sulfidic materials* occur within the upper 1.5 m of the profile.
Sulfidic [EU]

  Note: The Sulfidic Great Group can be replaced by the following Great Groups where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *hypersulfidic material* occur within the upper 1.5 m of the profile. Monohypersulfidic [IX]
- Other soils in which *hypersulfidic material* occurs within the upper 1.5 m of the profile. Hypersulfidic [IZ]
- Soils in which both *monosulfidic material* and *hyposulfidic material* occur within the upper 1.5 m of the profile. Monohyposulfidic [JA]
- Other soils with *hyposulfidic material* within the upper 1.5 m of the profile.
Hyposulfidic [JC]
- Soils with a *petroferric horizon* within the *soil profile*. Petroferric [EA]
- Soils which are *calcareous* throughout the *soil profile*, or at least below the A1 or *Ap horizon* or to a depth of 0.2 m if the *A1 horizon* is only *weakly developed*, and do not have a *clear or abrupt textural B horizon*.
Calcarosolic [CB]
- Soils with a *clear or abrupt textural B horizon* and the *major part* of the upper 0.2 m of the *B2 horizon* is *strongly acid*. Kurosolic [CX]
- Soils with a *clear or abrupt textural B horizon* which is *sodic* and not *strongly acid* in the *major part* of the upper 0.2 m of the *B2 horizon*.
Sodosolic [EQ]

- •• Other soils with a *clear or abrupt textural B horizon* and the pH_w in the *major part* of the upper 0.2 m of the *B2 horizon* is not *strongly acid*. **Chromosolic [BG]**
- •• Soils with structured *B2 horizons* and which apart from wetness fulfil the requirements for Dermosols. **Dermosolic [FQ]**
- •• Other soils with *B2 horizons* and which apart from wetness fulfil the requirements for Kandosols. **Kandosolic [FR]**
- •• Soils that apart from wetness fulfil the requirements for Arenosols. **Arenosolic [JM]**
- •• Soils that apart from wetness fulfil the requirements for Tenosols. **Tenosolic [GT]**
- •• Soils that apart from wetness fulfil the requirements for Rudosols. **Rudosolic [GR]**

Subgroups

No Subgroups for the Subtidal, Subaqueous, Supratidal, Extratidal and Hypersalic Hydrosols are formally proposed at present because of insufficient data.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

Subgroups of Intertidal Hydrosols

The following three Subgroups will only be applicable to the Histic-Hypersulfidic and Histic-Hyposulfidic Great Groups.

- Soils in which the *organic materials* are dominated by fibric *peat*. **Fibric [BW]**
- Soils in which the *organic materials*, other than fibric *peat*, are dominated by hemic *peat*. **Hemic [CE]**
- Soils in which the *organic materials*, other than fibric *peat*, are dominated by sapric *peat*. **Sapric [EH]**

Subgroups of Salic Hydrosols

The following three Subgroups have been identified for several Great Groups in the Salic Suborder. Other possibly relevant Subgroups may be found listed below in the Subgroups for the Redoxic and Oxyaquic Suborders.

- Soils with *sulfidic materials* in the A or near surface *horizons* and which directly overlie a *calcrete pan*. **Episulfidic-Petrocalcic [HM]**

- Other soils with *sulfidic materials* in the A or near surface *horizons*. Episulfidic [HL]
- Soils that directly overlie a *calcrete pan*. Petrocalcic [DZ]

Subgroups of Redoxic and Oxyaquic Hydrosols

It is thought that the following Subgroups will cater for most situations, although obviously some will not be relevant for particular Great Groups. As examples, the Acidic Subgroups will not be required for the Kurosolic Great Groups, nor the *Sodic* and Natric classes for the Sodosolic Great Group. Although presently not listed, a Petrocalcic Subgroup may be required for the Calcarosolic Great Group. If so, a definition is available above. Some additional Subgroups will be required for the Sulfuric and Sulfidic Great Groups as knowledge of these soils increases, for example a possible subdivision could be based on the nature of the *soil profile* above the sulfuric or *sulfidic materials* that commonly occur as a D horizon. In the case of the Rudosolic and Tenosolic Great Groups, the most appropriate Subgroups will be those used for the relevant Suborders and Great Groups of Rudosols and Tenosols.

- Soils that have been partly modified by high temperature burning of *organic materials*. Such soils have surface *layers* that comprise >20% of *fusic material*. Fusic [IT]
- Soils with a *peaty horizon* and a *thin ironpan* that occurs within or directly underlying the *B horizon*. Peaty-Placic [GD]
- Other soils with a *peaty horizon*. Peaty [DW]
- Soils with a *humose horizon* and a *B2 horizon* in which the *major part* has an exchangeable Ca/Mg ratio of less than 0.1. Humose-Magnesic [CL]
- Soils with a *humose horizon* and the *major part* of the *B2 horizon* is *strongly acid*. Humose-Acidic [GY]
- Soils with a *humose horizon* and at least some part of the B or BC horizon is *calcareous*. Humose-Calcareous [GU]
- Soils with a *humose horizon* and a *conspicuously bleached A2 horizon*. Humose-Bleached [EY]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon* and a *B2 horizon* in which the *major part* has an exchangeable Ca/Mg ratio of less than 0.1. Melacic-Magnesic [DH]
- Soils with a *melacic horizon* and a *conspicuously bleached A2 horizon*. Melacic-Bleached [EZ]
- Other soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon* and a *conspicuously bleached A2 horizon*. Melanic-Bleached [DL]

- Soils with a *melanic horizon* and a *B horizon* in which at least 0.3 m has *vertic properties*. Melanic-Vertic [DN]
- Soils with a *melanic horizon* and the *major part* of the *B2 horizon* is *strongly acid*. Melanic-Acidic [FV]
- Other soils with a *melanic horizon*. Melanic [DK]
- Soils with a *conspicuously bleached A2 horizon* and a *B horizon* in which at least 0.3 m has *vertic properties*. Bleached-Vertic [BB]
- Other soils with a *B horizon* in which at least 0.3 m has *vertic properties*. Vertic [EX]
- Soils with a *ferric horizon* within the *soil profile* and a *B2 horizon* in which the *major part* is *strongly acid*. Ferric-Acidic [GW]
- Soils with a *ferric horizon* within the *soil profile* and a *B horizon* in which at least the lower part is *sodic*. Ferric-Sodic [HC]
- Soils with a *conspicuously bleached A2 horizon* and a *ferric horizon* within the *soil profile*. Bleached-Ferric [AV]
- Other soils with a *ferric horizon* within the *soil profile*. Ferric [BU]
- Soils with a *manganic horizon* within the *soil profile* and a *B2 horizon* in which the *major part* is *strongly acid*. Manganic-Acidic [GX]
- Soils with a *conspicuously bleached A2 horizon* and a *manganic horizon* within the *soil profile*. Bleached-Manganic [AY]
- Other soils with a *manganic horizon* within the *soil profile*. Manganic [DC]
- Soils with a *siliceous pan* in the lower A and/or upper *B horizon*. Silpanic [EM]
- Soils in which the *major part* of the *B2 horizon* is *strongly acid* and at least the lower part is *sodic*. Acidic-Sodic [HO]
- Soils with a *conspicuously bleached A2 horizon* and a *B2 horizon* in which the *major part* is *strongly acid*. Bleached-Acidic [AU]
- Other soils with a *B2 horizon* in which the *major part* is *strongly acid*. Acidic [AI]
- Soils that have an exchangeable Ca/Mg ratio of less than 0.1 in the *major part* of the *B2 horizon*, and the *major part* of the upper 0.2 m of the *B2 horizon* is *sodic*. Magnesic-Natric [GP]
- Other soils in which the *major part* of the upper 0.2 m of the *B2 horizon* is *sodic*. Natric [FD]
- Soils with a *conspicuously bleached A2 horizon* and a *B horizon* in which at least the lower part is *sodic*. Bleached-Sodic [BA]

- Other soils with a *B horizon* in which at least the lower part is *sodic* Sodic [EO]
- Soils with a *reticulate horizon* below the *B2 horizon*. Reticulate [EF]
- Soils with a *conspicuously bleached A2 horizon* and a *B2 horizon* in which the *major part* has an exchangeable Ca/Mg ratio of less than 0.1. Bleached-Magnesic [AX]
- Soils with an exchangeable Ca/Mg ratio of less than 0.1 in the *major part* of the *B2 horizon*. Magnesic [DB]
- Other soils with a *conspicuously bleached A2 horizon*. Bleached [AT]
- Soils in which the *major part* of the *B2 horizon* is *dystrophic*. Dystrophic [AF]
- Soils in which the *major part* of the *B2 horizon* is *mesotrophic*. Mesotrophic [AG]
- Soils in which the *major part* of the *B2 horizon* is *eutrophic* but the *B* and *BC horizons* are not *calcareous*. Eutrophic [AH]
- Soils in which at least some part of the B or the BC horizon is *calcareous*. Calcareous [BC]

Family Criteria

The classes below are primarily for use in the Redoxic and Oxyaquic Suborders, and possibly the Extratidal and Salic Suborders. The criteria may be partly applicable to the Supratidal and Hypersalic Suborders, for example using the terms surface soil and maximum subsoil texture. The different *A horizon* thickness criteria for Great Groups with a *clear or abrupt textural B horizon* allows alignment with their adjacent but drier equivalent Orders.

A horizon thickness plus the thickness of organic horizons (O2, P1 or P2) if present (for Chromosolic, Kurosolic and Sodosolic Great Groups)

Thin	[A]	<0.1 m
Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

A1 horizon thickness plus the thickness of organic horizons (O2, P1 or P2) if present (for all other Great Groups)

Thin	[A]	<0.1 m
Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

Gravel of the surface and *A1 horizon*

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

A1 horizon texture or texture of organic horizon (O2, P1 or P2) if present

Peaty	[J]	Dominated by *organic materials*
Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

B horizon maximum texture[10]

Sandy	**[K]**	S-LS-CS (≤10% clay)
Loamy	**[L]**	SL-L (10–20% clay)
Clay loamy	**[M]**	SCL-CL (20–35% clay)
Silty	**[N]**	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	**[O]**	LC-MC-HC (>35% clay)

Soil depth

Very shallow	**[T]**	<0.25 m
Shallow	**[U]**	0.25–<0.5 m
Moderately deep	**[V]**	0.5–<1.0 m
Deep	**[W]**	1.0–<1.5 m
Very deep	**[X]**	1.5–5 m
Giant	**[Y]**	>5 m

Water repellence of surface soil

Non water repellent	**[NR]**	Water absorbed in 10 seconds or less
Water repellent	**[WR]**	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	**[SR]**	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

[10] This refers to the most clayey field texture category.

Kandosols [KA]

[Pronounced Can-doh-sols]

Concept

This Order accommodates those soils that lack strong texture contrast, have massive or only weakly structured *B horizons*, and are not *calcareous* throughout. The soils of this Order range throughout the continent, often occurring locally as very large areas.

Definition

Soils other than Hydrosols that have all of the following:

1. *B2 horizons* in which the *major part* has a *grade of pedality* that is massive or weak.
2. A maximum clay content in some part of the *B2 horizon* that exceeds 15% (i.e. heavy sandy loam [SL+] or heavier).
3. Do not have a *clear or abrupt textural B horizon*.
4. Are not *calcareous* throughout the *solum*, or below the A1 or *Ap horizon* or to a depth of 0.2 m if the *A1 horizon* is only *weakly developed*.

Comment

Because of the lack of clearly defined *horizons* in some of these soils (particularly the red forms) with thick sola, there can be argument as to how to identify the limits of the *B2 horizon*.

There may be difficulty differentiating between Kandosols and Arenosols, where texture and horizon development is weak and sandy textures dominate. Some Kandosols have very thick *A* and/or *B1 horizons* with sandy textures that overlie at >1.0 m deep, and *B2t horizons* that exceed 15% clay.

Suborders

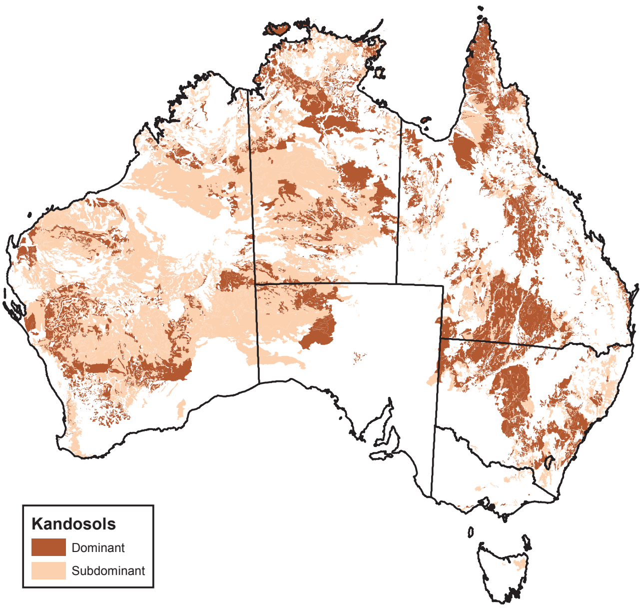
The dominant colour class in the *major part* of the upper 0.5 m of the *B2 horizon* (or the *major part* of the entire *B2 horizon* if it is less than 0.5 m thick) is:

••• Red. Red [AA]
••• Brown. Brown [AB]

••• Yellow. Yellow [AC]

••• Grey. Grey [AD]

••• Black. Black [AE]



Distribution of Kandosols in Australia.

Great Groups

It is thought that most of the following Great Group categories will be appropriate for the various Suborders. At present the Duric and Mellic Great Groups are only known to occur in Red or Brown Kandosols, particularly the former. The Duric soils are confined to the arid zone.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

•• Soils with a *red-brown hardpan* either within or directly underlying the *B horizon*. Duric [BJ]

•• Soils with a *B horizon* either containing or directly underlain by *ferricrete*, a *petroferric horizon*, or a *petroreticulate horizon*. Petroferric [EA]

•• Soils with a *B horizon* that is not *calcareous* and which directly overlies a *calcrete pan*. Petrocalcic [DZ]

•• Soils with a *thin ironpan* that occurs within or directly underlying the *B horizon*. Placic [EC]

- •• Soils that are underlain within 0.5 m of the surface by *hard* unweathered rock or other *hard* materials; or partially weathered or decomposed rock or saprolite. Leptic [CY]
- •• Soils with massive to weakly structured (~10 mm subangular blocky parting to finer granules) *B horizons* that are very porous with a weak consistence strength when moist. Bulk density appears to be relatively low. (See Comment below.) Mellic [DO]
- •• Soils that have *andic properties* and have formed in basaltic *tephric materials* that may be visibly stratified. Andic [AK]
- •• Soils with an exchangeable Ca/Mg ratio of less than 0.1 in the *major part* of the *B2 horizon*. Magnesic [DB]
- •• Soils in which the *major part* of the *B2 horizon* is *dystrophic*. Dystrophic [AF]
- •• Soils in which the *major part* of the *B2 horizon* is *mesotrophic*. Mesotrophic [AG]
- •• Soils in which the *major part* of the *B2 horizon* is *eutrophic* but the *B* and *BC horizons* are not *calcareous*. Eutrophic [AH]
- •• Soils in which the carbonate is evident only as a slight to moderate effervescence (1 M HCl), and/or contain less than 2% soft finely divided carbonate, and have less than 20% *hard* carbonate nodules or concretions. Hypocalcic [CV]
- •• Soils with a *calcareous horizon* containing more than 50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. Lithocalcic [DA]
- •• Soils with a *calcareous horizon* containing 20–50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. Supracalcic [FB]
- •• Soils with a *calcareous horizon* containing more than 20% of mainly soft, finely divided carbonate, and 0–20% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions, and/or carbonate-coated *gravel*. Hypercalcic [CQ]
- •• Other soils with a *calcareous horizon*. (See *carbonate classes* in glossary.) Calcic [BD]

Comment

The *calcareous* classes above approximately correspond to those of Wetherby and Oades (1975) as follows: Hypocalcic – Class IV, Lithocalcic – Class III B and IIIC, Supracalcic – Class III B, Hypercalcic – Class III A, Calcic – Class I and IIIA. In the Lithocalcic and Supracalcic classes the coarse fragments may be >0.2 m in size and soft carbonate may or may not be present.

The Mellic soils are very common but little-known acid soils in the high rainfall–high altitude forested areas of south-eastern mainland Australia and Tasmania. Structure is often difficult to determine because of weak consistence strength and the usual presence of more than 20% of rock fragments throughout the profile. Any peds present do not possess smooth faces.

Subgroups

It is thought that the following Subgroups will cater for most situations, although obviously some will not be relevant for particular Great Groups of particular Suborders. As an example, the various acidic Subgroups will not be required for the *calcareous* Great Groups.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- Soils with a *humose horizon* and the *major part* of the *B2 horizon* is mottled. Humose-Mottled [CM]
- Soils with a *humose horizon* and the *major part* of the *B2 horizon* is *strongly acid*. Humose-Acidic [GY]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon* and the *major part* of the *B2 horizon* is mottled. Melacic-Mottled [DI]
- Other soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon* and the *major part* of the *B2 horizon* is mottled. Melanic-Mottled [DM]
- Soils with a *melanic horizon* and the *major part* of the *B2 horizon* is *strongly acid*. Melanic-Acidic [FV]
- Other soils with a *melanic horizon*. Melanic [DK]
- Soils with an *argic horizon* within the *B horizon*. Argic [AP]
- Soils with a *bauxitic horizon* within the *B horizon*. Bauxitic [AS]
- Soils with a *ferric horizon* within the *solum* and a *B2 horizon* in which the *major part* is *strongly acid*. Ferric-Acidic [GW]
- Soils with a *ferric horizon* within the *solum* and a *B horizon* in which at least the lower part is *sodic*. Ferric-Sodic [HC]
- Soils with a *conspicuously bleached A2 horizon* and a *ferric horizon* within the *solum*. Bleached-Ferric [AV]

- Other soils with a *ferric horizon* within the *solum*. Ferric [BU]
- Soils with a *manganic horizon* within the *solum* and a *B2 horizon* in which the *major part* is *strongly acid*. Manganic-Acidic [GX]
- Soils with a *conspicuously bleached A2 horizon* and a *manganic horizon* within the *solum*. Bleached-Manganic [AY]
- Other soils with a *manganic horizon* within the *solum*. Manganic [DC]
- Soils in which the *major part* of the *B2 horizon* is *strongly acid* and at least the lower part of the *B horizon* is *sodic*. Acidic-Sodic [HO]
- Soils with a *conspicuously bleached A2 horizon* and a *B2 horizon* in which the *major part* is *strongly acid*. Bleached-Acidic [AU]
- Soils in which the *major part* of the *B2 horizon* is *strongly acid* and mottled. Acidic-Mottled [AJ]
- Other soils with a *B2 horizon* in which the *major part* is *strongly acid*. Acidic [AI]
- Soils with a *conspicuously bleached A2 horizon* and a *B horizon* in which at least the lower part is *sodic*. Bleached-Sodic [BA]
- Soils in which the *major part* of the *B2 horizon* is mottled and at least the lower part of the *B horizon* is *sodic*. Mottled-Sodic [HB]
- Other soils with a *B horizon* in which at least the lower part is *sodic*. Sodic [EO]
- Soils with a *conspicuously bleached A2 horizon* and the *major part* of the *B2 horizon* is mottled. Bleached-Mottled [AZ]
- Other soils with a *conspicuously bleached A2 horizon*. Bleached [AT]
- Soils with a *reticulate horizon* below the *B2 horizon*. Reticulate [EF]
- Other soils in which the *major part* of the *B2 horizon* is mottled. Mottled [DQ]
- Other soils in which the *major part* of the *B2 horizon* is whole coloured. Haplic [CD]

Comment

In some of the *Dystrophic* Kandosols there may be a future need to modify the definition of *sodic* Subgroups (see *ESP*). As in Chromosols, Dermosols and Ferrosols, Haplic is the most common Subgroup. While this could indicate a need for further subdivision, it is difficult to find criteria that could be used.

Family Criteria

A1 horizon thickness plus the thickness of organic horizons (O2, P1 or P2) if present

Thin	[A]	<0.1 m
Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

Gravel of the surface and *A1 horizon*

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

A1 horizon texture or texture of organic horizons (O2, P1 or P2) if present

Peaty	[J]	Dominated by *organic materials*
Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

B horizon maximum texture[11]

Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

Soil depth

Very shallow	[T]	<0.25 m
Shallow	[U]	0.25–<0.5 m
Moderately deep	[V]	0.5–<1.0 m
Deep	[W]	1.0–<1.5 m
Very deep	[X]	1.5–5 m
Giant	[Y]	>5 m

[11] This refers to the most clayey field texture category.

Water repellence of surface soil

Non water repellent	**[NR]**	Water absorbed in 10 seconds or less
Water repellent	**[WR]**	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	**[SR]**	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

Kurosols [KU]

[Pronounced Cure-oh-sols]

Concept

Soils with strong texture contrast between *A horizons* and *strongly acid B horizons*. Many of these soils have some unusual subsoil chemical features (high magnesium, sodium and aluminium).

Definition

Soils other than Hydrosols with a *clear or abrupt textural B horizon* and in which the *major part* of the upper 0.2 m of the B2t horizon (or the *major part* of the entire B2t horizon if it is <0.2 m thick) is *strongly acid*.

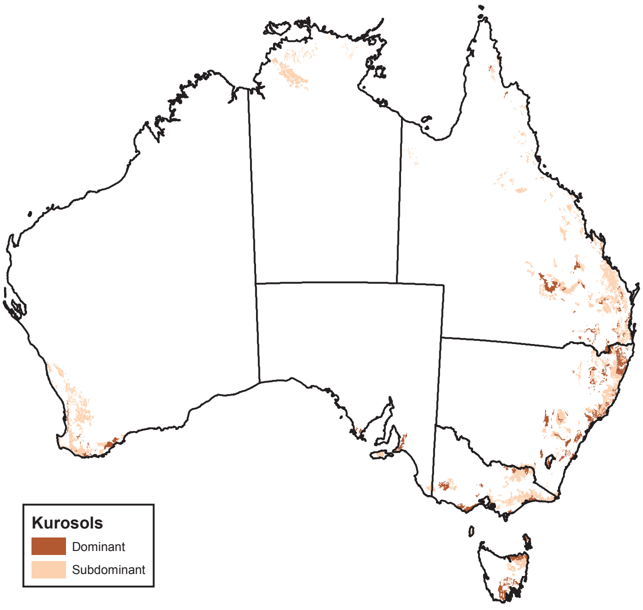
Comment

The relevance of sodicity in *strongly acid* soils is open to question as in theory the presence of aluminium in such soils should counterbalance the usual deleterious effect of sodium (via dispersion) on soil physical properties. Unpublished data from many localities in Australia imply that for *B horizons* the critical limits of pH_w *5.5* and *ESP* of 6 to distinguish dispersive and non-dispersive soils seems to generally work in practice, although as might be expected, some soils do not behave as predicted. For this reason, sodicity is also used in Kurosols, but at a lower hierarchical level, to cater for those soils that have an *ESP* >6 and may disperse in spite of having a pH_w less than 5.5. The role of the high exchangeable magnesium in many Kurosols is largely unknown.

Suborders

The dominant colour class in the *major part* of the upper 0.2 m of the B2t horizon (or the *major part* of the entire B2t horizon if it is <0.2 m thick) is:

••• Red. Red [AA]
••• Brown. Brown [AB]
••• Yellow. Yellow [AC]
••• Grey. Grey [AD]
••• Black. Black [AE]



Distribution of Kurosols in Australia.

Great Groups

These will vary somewhat among the various colour class Suborders, but it is likely that the subdivisions given below will apply to most.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- •• Soils with a *petroferric horizon* within the *solum*. Petroferric [EA]
- •• Soils with an exchangeable Ca/Mg ratio of less than 0.1 in the *major part* of the B2t horizon, and the *major part* of the upper 0.2 m of the B2t horizon is *sodic*. Magnesic-Natric [GP]
- •• Other soils with an exchangeable Ca/Mg ratio of less than 0.1 in the *major part* of the B2t horizon. Magnesic [DB]
- •• Other soils in which the *major part* of the upper 0.2 m of the B2t horizon is *sodic*. Natric [FD]
- •• Soils in which the *major part* of the B2t horizon is *dystrophic*. Dystrophic [AF]
- •• Soils in which the *major part* of the B2t horizon is *mesotrophic*. Mesotrophic [AG]
- •• Soils in which the *major part* of the B2t horizon is *eutrophic*. Eutrophic [AH]

Comment

A feature of the soils classified is the common occurrence of high subsoil exchangeable magnesium with or without sodium. In spite of an upper B2t horizon that is *strongly acid*, *Mesotrophic* Great Groups are more common than the *Dystrophic* forms. This is often related to relatively high magnesium values.

Subgroups

The Subgroups listed will not all be relevant for every Great Group, for example *Sodic* classes will not be required for the Natric Great Groups.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- Soils with a *humose horizon* and a *conspicuously bleached A2 horizon*. Humose-Bleached [EY]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon* and a *conspicuously bleached A2 horizon*. Melacic-Bleached [EZ]
- Other soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon* and a *B horizon* in which at least 0.3 m has *vertic properties*. Melanic-Vertic [DN]
- Other soils with a *melanic horizon*. Melanic [DK]
- Soils with a *conspicuously bleached A2 horizon* and a *B horizon* in which at least 0.3 m has *vertic properties*. Bleached-Vertic [BB]
- Other soils with a *B horizon* in which at least 0.3 m has *vertic properties*. Vertic [EX]
- Soils with a *conspicuously bleached A2 horizon* and a *ferric horizon* within the *solum*. Bleached-Ferric [AV]
- Other soils with a *ferric horizon* within the *solum*. Ferric [BU]
- Soils with a *conspicuously bleached A2 horizon* and a *manganic horizon* within the *solum*. Bleached-Manganic [AY]
- Other soils with a *manganic horizon* within the *solum*. Manganic [DC]
- Soils with a *conspicuously bleached A2 horizon* and a *B horizon* in which at least the lower part is *sodic*. Bleached-Sodic [BA]
- Soils in which the *major part* of the B2t horizon is mottled and at least the lower part of the *B horizon* is *sodic*. Mottled-Sodic [HB]

- Other soils with a *B horizon* in which at least the lower part is *sodic*. **Sodic [EO]**
- Soils with a *conspicuously bleached A2 horizon* and the *major part* of the B2t horizon is mottled. **Bleached-Mottled [AZ]**
- Other soils with a *conspicuously bleached A2 horizon*. **Bleached [AT]**
- Soils with a *reticulate horizon* below the B2t horizon. **Reticulate [EF]**
- Other soils in which the *major part* of the B2t horizon is mottled. **Mottled [DQ]**
- Other soils in which the *major part* of the B2t horizon is whole coloured. **Haplic [CD]**

Comment

A significant proportion of the soils classified to date have mottled *B2t horizons*, which suggests a trend to poorer internal drainage in the Kurosols compared to Chromosols.

Family Criteria

A horizon thickness

Thin	[A]	<0.1 m
Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

Gravel of the surface and *A1 horizon*

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

A1 horizon texture

Peaty	[J]	Dominated by *organic materials*
Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)

B horizon maximum texture[12]

Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

Soil depth

Very shallow	[T]	<0.25 m
Shallow	[U]	0.25–<0.5 m
Moderately deep	[V]	0.5–<1.0 m
Deep	[W]	1.0–<1.5 m
Very deep	[X]	1.5–5 m
Giant	[Y]	>5 m

Water repellence of surface soil

Non water repellent	[NR]	Water absorbed in 10 seconds or less
Water repellent	[WR]	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	[SR]	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

[12] This refers to the most clayey field texture category.

Organosols [OR]

[Pronounced Or-gan-oh-sols]

Concept

This Order caters for soils dominated by *organic materials*. Although they are found from the wet tropics to the alpine regions, areas are mostly small except in south-west Tasmania. There have been few previous attempts to subdivide these soils and substantial data are limited to Tasmania.

Definition

Soils that are not regularly inundated by saline tidal waters and either:

1. Have more than 0.4 m of *organic materials* within the upper 0.8 m. The required thickness may either extend down from the surface or be taken cumulatively within the upper 0.8 m, or
2. Have *organic materials* extending from the surface to a minimum depth of 0.1 m; these either overlie a mineral soil horizon or *unconsolidated mineral materials* no thicker than the *organic materials* above, or directly overlie rock or other *hard layers*, partially weathered or decomposed rock or saprolite, or overlie fragmental material such as *gravel*, cobbles or stones in which the interstices are filled or partially filled with *organic material*. In some soils there may be *layers* of *humose*, *melacic* and/or *melanic horizon* material underlying the *organic materials* and overlying the substrate.

Comment

Soils with *peaty horizons* that do not meet the *organic material* requirements of Organosols are catered for in other Orders, commonly Hydrosols. Organosols may classify as a buried soil if overlain by aeolian or fluvial deposits that may have undergone other developmental processes. If the overlying material is less than 0.3 m and can only qualify as a Rudosol, it is regarded as a depositional phase of the Organosol below.

Distribution of Organosols in Australia.

Suborders

••• Soils in which the dominant *organic material*, by thickness, is fibric *peat*. **Fibric [BW]**

••• Other soils in which the dominant *organic material*, by thickness, is hemic *peat*. **Hemic [CE]**

••• Other soils in which the dominant *organic material*, by thickness, is sapric *peat*. **Sapric [EH]**

Comment

The terms fibric, hemic and sapric are essentially the same as defined in the *World Reference Base* (2015) and *Soil Taxonomy* (Soil Survey Staff 2014) and give an indication of the relative decomposition of the *organic materials*. If the proportions of peats in a profile are such that no *peat* type is dominant, then the *peat* type with the most advanced level of decomposition should be selected.

In some north Queensland seasonal swamps, thick peats can have 0.3–0.4 m of sapric over hemic and/or fibric *peat*. Conversely many organic moorland soils found in the remote south-western wilderness area of Tasmania often grade from fibric and hemic *peat* through to an underlying sapric *peat*. When more data are available it may be necessary to modify the Suborder definitions to cater for soils where the type of *peat* changes with depth.

Great Groups

It is likely that not all of the Great Groups below will be applicable to each Suborder. It is also likely that other Great Groups will be required as knowledge increases.

- Soils that are more or less freely drained and are never saturated for more than several days unless rain is falling and contain *organic materials* that occur as in Definition 2 of Organosols. Folic [IF]

- Soils in which *sulfuric material* (at least 0.15 m thick) occurs within the upper 1.5 m of the profile. Sulfuric [EV]

  Note: The Sulfuric Great Group can be replaced by the following Great Group where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *sulfuric material* (at least 0.15 m thick) occur within the upper 1.5 m of the profile. Monosulfidic-Sulfuric [IW]

- Soils in which *sulfidic materials* occur within the upper 1.5 m of the profile. Sulfidic [EU]

  Note: The Sulfidic Great Group can be replaced by the following Great Groups where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *hypersulfidic material* occur within the upper 1.5 m of the profile. Monohypersulfidic [IX]

- Other soils in which *hypersulfidic material* occurs within the upper 1.5 m of the profile. Hypersulfidic [IZ]

- Soils in which both *monosulfidic material* and *hyposulfidic material* occur within the upper 1.5 m of the profile. Monohyposulfidic [JA]

- Other soils with *hyposulfidic material* within the upper 1.5 m of the profile. Hyposulfidic [JC]

- Soils in which the *major part* of the *organic materials* is *calcareous*. Calcareous [BC]

- Soils in which the *major part* of the *organic materials* is not *calcareous* but is not *strongly acid*. Basic [AR]

- Soils in which the *major part* of the *organic materials* is *strongly acid*. Acidic [AI]

Comment

The Sulfuric and Sulfidic Great Groups introduced in the second edition can vary considerably in their properties. The *pH* buffering capacity in particular is an important factor in assessing risk and managing disturbance of these soils. Some low density Hypersulfidic Organosols, especially peats with many pores that are open and connected, have extremely low *pH* buffering capacity. When oxidised, these soils rapidly develop extremely acidic *sulfuric materials* (*pH* 1.5–2.5). As knowledge increases about Sulfidic and Sulfuric Organosols, further modification of Great Group definitions may be needed.

Subgroups

The following Subgroups may not be relevant to all Great Groups of each Suborder, and future investigations may reveal additional Subgroups.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- Soils in which the *organic materials* directly overlie *hard* rock. **Lithic [CZ]**
- Soils in which the *organic materials* directly overlie partially weathered or decomposed rock or saprolite. **Paralithic [DU]**
- Soils with a *marl layer* either within or immediately below the section containing the *organic materials*. **Marly [DD]**
- Soils in which the *organic materials* directly overlie fragmental material such as *gravel*, cobbles or stones in which the interstices are filled or partially filled with *organic material*. **Rudaceous [HD]**
- Soils in which *layers* of *humose*, *melanic* and/or *melacic horizon* material underlie the *organic materials* and overlie the substrate. **Modic [IJ]**
- Soils with a *thin ironpan* below the *organic materials*. **Placic [EC]**
- Soils with a *layer* (or *layers*) of mineral horizon or unconsolidated mineral material within or below the *organic materials* but within 0.8 m of the surface. **Terric [FS]**
- Other soils with a *layer* (or *layers*) of unconsolidated mineral material that occurs below 0.8 m of the surface. **Regolithic [GF]**

Family Criteria

Texture classes specific to *organic materials* (and consistent with horizon definitions in the *Field Handbook*) describe the dominant texture of the uppermost *organic materials*, *horizons* or *layers*. These classes provide a useful insight to the formation processes of and inherent vulnerabilities to the uppermost *organic materials*.

Granular is applied if there is a *layer* at least 0.2 m thick that has a distinct granular or subangular blocky type of pedality (see *Field Handbook*). This condition occurs in some *peat* soils that have either naturally dried out, or have been drained or drained and cultivated, and are also known as earthy or ripened peats. In Australia it is known to occur with sapric peats, but it is uncertain if it occurs with hemic or fibric peats.

Ashy and Vitric reflect the influence of fire.

Nature of altered *organic materials*

(use only if feature present; choose dominant feature if more than one present)

Granular	[P]	Granular or subangular type of pedality
Ashy	[HZ]	Presence of *ash material*
Vitric	[JZ]	≥20% *fusic material*

Cumulative thickness of uppermost *organic materials*

(sum of the consecutive *O1*, *O2*, *P1* and/or *P2 horizons*)

Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

Gravel of the surface horizon

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

Dominant type or texture of uppermost *organic materials* (O2, P1 or P2 if present)

Surface *organic material* absent	[Z]
Fibric *peat*	[OA]
Hemic *peat*	[OB]
Sapric *peat*	[OC]
Sandy *peat*	[OD]
Loamy *peat*	[OE]
Clayey *peat*	[OF]

Texture of the layer directly underlying the deepest *organic materials*

Texture material absent	[**Z**]	
Sandy	[**K**]	S-LS-CS (≤10% clay)
Loamy	[**L**]	SL-L (10–20% clay)
Clay loamy	[**M**]	SCL-CL (20–35% clay)
Silty	[**N**]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[**O**]	LC-MC-HC (>35% clay)

Soil depth

(measured from the soil surface including organic *horizons*)

Very shallow	[**T**]	<0.25 m
Shallow	[**U**]	0.25–<0.5 m
Moderately deep	[**V**]	0.5–<1.0 m
Deep	[**W**]	1.0–<1.5 m
Very deep	[**X**]	1.5–5 m
Giant	[**Y**]	>5 m

Podosols [PO]

[Pronounced Pod-oh-sols]

Concept

Soils with *B horizons* dominated by the accumulation of compounds of organic matter, aluminium and/or iron. These soils are recognised worldwide, and Australia is particularly noted for its 'giant' forms. Podosols are typically found in close proximity to the coast and on islands comprised of quartz sand.

Definition

Soils that possess either a *Bs horizon* (visible dominance of iron compounds), a *Bhs horizon* (organic-aluminium and iron compounds), or a *Bh horizon* (organic-aluminium compounds). These *horizons* may occur singly in a profile or in combination (see *Podosol diagnostic horizons*).

Comment

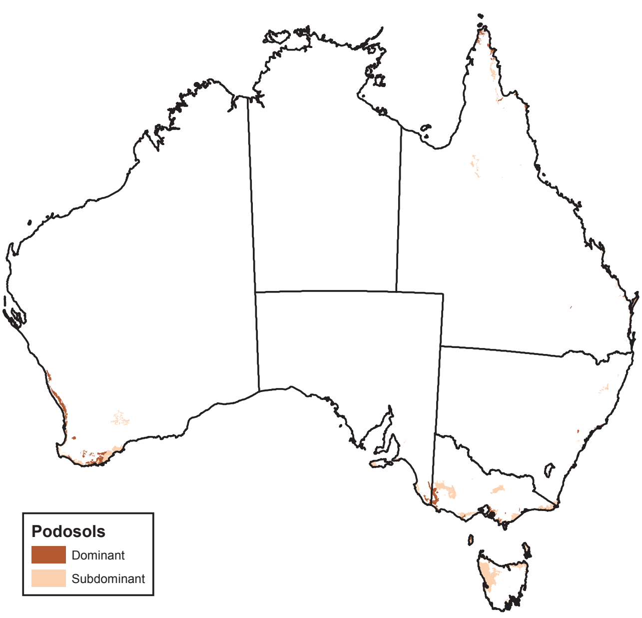
Extensive revisions of the classification of Spodosols and Podzols have taken place in the USA (with worldwide input) and New Zealand. It is clear that there is considerable diversity of opinion on the desirability, nature and efficacy of chemical criteria to define Spodosols/Podzols. For this reason the present proposal for Australian 'podzols' has deliberately avoided the use of chemical diagnostic criteria. Some Podosols with deep diagnostic *B horizons* may classify initially as Bleached Arenosols. Only deep examination of the soil profile can confirm the Order of such soils.

Suborders

These are based on soil and site drainage conditions. The intention is to separate soils with no short-term saturation in the *B horizon*, those with short-term saturation of the *B horizon*, and those that are saturated for long periods in the *B horizon*.

••• Soils with free drainage (i.e. rapidly drained). There is no restriction to through drainage in the *B horizon* or within the substrate. There is no perching of water within the *B horizon* or saturation due to a high groundwater table. The *B horizons* are weakly coherent and porous. They are often brightly coloured, and lack evidence of seasonal reduction. **Aeric [AL]**

- ••• Soils with short-term saturation in the *B horizon*. The saturation may be caused by impedance within the *B horizon*, perching of water by substrate material, or by seasonally high groundwater tables. The duration of saturation may range from several days to several weeks but is insufficient to reduce and remove significant amounts of the accumulated iron. However, there may be a greater accumulation of organic compounds and less iron in the zone of maximum saturation. Semiaquic [EJ]
- ••• Soils with long-term saturation in the *B horizon* and *sulfuric material* (at least 0.15 m thick) is present in the *A* or *B horizons*. Aquic-Sulfuric [JD]
- ••• Soils with long-term saturation in the *B horizon* and *hypersulfidic material* is present in the *A* or *B horizons*. Aquic-Hypersulfidic [JE]
- ••• Soils with long-term saturation in the *B horizons*. The saturation may be caused as in the semiaquic soils but the duration is of the order of months. The period of saturation is sufficient to reduce most iron compounds and move them out of the *B horizon*, hence *Bh horizons* are usually prominent. Aquic [AM]



Distribution of Podosols in Australia.

Great Groups

Classes are based on observable *B horizon* characteristics reflecting the dominance of organic or iron compounds and their distribution in the accumulation zone. The organic accumulations can usually be recognised by their dark colours and the iron compounds by generally bright colours. Aluminium is always present, usually complexed by organic matter and therefore not usually visible, except in some *horizons* where large amounts of amorphous aluminium and silica (imogolite-allophane complexes) may induce a yellowish brown colouration. Yellowish brown bands in poorly-drained *B horizons* should not be interpreted as evidence of iron compounds without chemical verification.

Aeric Podosols

- •• Soils with a *pipey B horizon*. Pipey [EB]
- •• Soils with only a *Bs horizon*. Sesquic [EK]
- •• Soils with only a *Bhs horizon*. Humosesquic [CO]
- •• Soils with a *Bhs/Bs horizon*. Humosesquic/Sesquic [IG]

Semiaquic Podosols

- •• Soils with a *pipey B horizon*. Pipey [EB]
- •• Soils with only a *Bs horizon*. Sesquic [EK]
- •• Soils with only a *Bhs horizon*. Humosesquic [CO]
- •• Soils with only a *Bh horizon*. Humic [CG]
- •• Soils with a *Bh/Bs horizon*. Humic/Sesquic [CJ]
- •• Soils with a *Bh/Bhs horizon*. Humic/Humosesquic [CI]
- •• Soils with a *Bh/Basi horizon*. Humic/Alsilic [IH]

Aquic-Sulfuric, Aquic-Hypersulfidic and Aquic Podosols

- •• Soils with only a *Bh/Basi horizon*. Humic [CG]
- •• Soils with a *Bh/Basi horizon*. Humic/Alsilic [IH]

Comment

In the soils classified the most common class in the Aeric Suborder is the Sesquic Great Group, but Humic is most common in the Semiaquic and Aquic Suborders.

Subgroups

Each class listed below may not be relevant for every Great Group of each Suborder.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- Soils with a *peaty horizon* and a *strongly coherent B horizon*. Peaty-Parapanic [DX]

- Soils with a *peaty horizon* and a *thin ironpan* that occurs within or directly underlying the *B horizon*. Peaty-Placic [GD]
- Other soils with a *peaty horizon*. Peaty [DW]
- Soils with a *humose horizon* and a *strongly coherent B horizon*. Humose-Parapanic [CN]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon* and a *strongly coherent B horizon*. Melacic-Parapanic [DJ]
- Other soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon*. Melanic [DK]
- Soils with a *densipan* present in the *A2 horizon* and a *thin ironpan* that occurs within or directly underlying the *B horizon*. Densic-Placic [HN]
- Other soils with a *densipan* present in the *A2 horizon*. Densic [BI]
- Other soils with a *thin ironpan* that occurs within or directly underlying the *B horizon*. Placic [EC]
- Soils with a *siliceous pan* directly underlying the *B horizon*. Silpanic [EM]
- Soils with a *ferric horizon* within the *B horizon*. Ferric [BU]
- Soils with a *strongly coherent B horizon*. Parapanic [DV]
- Other soils with a *weakly coherent B horizon*. Fragic [BY]

Comment

The term ‘parapanic’ is meant to imply ‘pan-like’. Note also that the *A1 horizons* of many Podosols may have a distinct surface *layer* of lighter coloured sand with clean quartz grains and discrete lumps of organic matter and charcoal, giving the *layer* a speckled appearance. Below this *layer*, a dark *A1 horizon* may occur. Because the great majority of Australian Podosols have a bleached *A2 horizon*, this attribute is not used in the classification. Similarly, the great majority have a *B horizon* pH_w of less than 5.5, hence acidic Subgroups have not been used.

Family Criteria

A1 horizon thickness plus the thickness of organic horizons (O2, P1 or P2) if present

Thin	[A]	<0.1 m
Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

Gravel of the surface and _A1 horizon_

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

A1 horizon texture or texture of organic horizons (O2, P1 or P2) if present

Peaty	[J]	Dominated by *organic materials*
Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

B horizon maximum texture[13]

Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

Soil depth

Very shallow	[T]	<0.25 m
Shallow	[U]	0.25–<0.5 m
Moderately deep	[V]	0.5–<1.0 m
Deep	[W]	1.0–<1.5 m
Very deep	[X]	1.5–5 m
Giant	[Y]	>5 m

[13] This refers to the most clayey field texture category.

***Water repellence* of surface soil**

Non water repellent	**[NR]**	Water absorbed in 10 seconds or less
Water repellent	**[WR]**	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	**[SR]**	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

Rudosols [RU]

[Pronounced Roo-doh-sols]

Concept

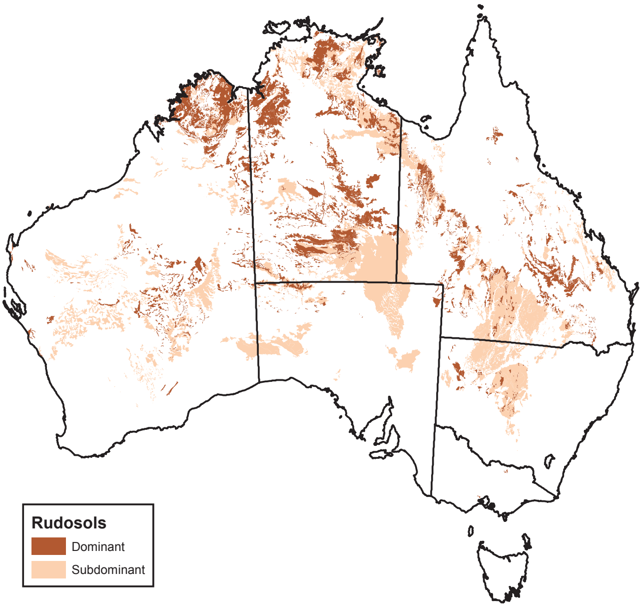
This Order is designed to accommodate soils that have little, if any, *pedologic organisation*. They are usually young soils in the sense that soil forming factors have had little time to pedologically modify parent rocks or sediments. The component soils can obviously vary widely in terms of texture and depth; many are stratified and some are highly saline. Data on some of them are very limited.

Definition

Soil with little, if any, (rudimentary) *pedologic organisation* apart from: (a) minimal development of an *A1 horizon*, or (b) the presence of less than 10% of *B horizon* material (including pedogenic carbonate) in fissures in the parent rock or saprolite. The soils are apedal or only weakly structured in the *A1 horizon* and show no pedological colour changes apart from the darkening of an *A1 horizon*. There is little or no texture or colour change with depth unless stratified or buried soils are present.

Comment

By definition, these soils will grade to Tenosols, so before deciding on the Order check the Tenosol definition as it will often be a matter of judgement as to which Order a particular soil is best placed. Arenic (sandy) Rudosols will grade to Arenosols, although by definition will have sand less than 1.0 m deep. Hydrosols are excluded on the basis that these will normally show some pedological development (e.g. mottling). A particular problem with the definition and subdivision of Rudosols is the difficulty in distinguishing between soil and 'non-soil' (see also 'What do we classify?'). In many instances they are classified on the basis of the nature of AC or C horizon materials or other substrates because these are the dominating features of the profile. It also follows that there may be difficulties in deciding if a soil is best classified as an Anthroposol or be regarded as an 'anthropic' Rudosol because the little-altered soil parent material may be human-made.



Distribution of Rudosols in Australia.

Rudosols in arid climatic zones form under a variety of processes (i.e. dust accretion, biological surface crusts, reduced leaching and more active wind and water erosion under sparse vegetation cover). The relative significance of these processes will differ from other climatic zones.

Suborders

- ••• Soils that are not highly saline (EC <2 dS m^{-1}; 1:5 H_2O) and dominantly consist of gypsum crystals that are sand-sized or finer. Hypergypsic [FJ]
- ••• Soils that are highly saline (EC >2 dS m^{-1}; 1:5 H_2O), often salt-encrusted, frequently stratified, but do not have a permanent or seasonal water table and do not show any evidence of episodic wetting by groundwater, such as mottling. Hypersalic [CS]
- ••• Soils that dominantly consist of fragments of shells and other aquatic skeletons (identifiable under a 10 × hand lens and often readily visible to the naked eye). Shelly [EL]
- ••• Soils in which the upper 0.5 m (or less if the profile is shallower) consists dominantly of *carbic materials*. Carbic [HG]
- ••• Soils that are underlain within 0.5 m of the surface by a *calcrete pan*; *hard* unweathered rock or other *hard* materials; or partially weathered or decomposed rock or saprolite. Leptic [CY]

••• Soils in which the profile is not or only slightly gravelly (<10%, 2 mm) throughout, either loose or only weakly coherent both moist and dry, and the texture is dominantly sandy (i.e. *field textures* of S-LS-CS) and there is no *layer* with a clay content of >15% (i.e. *field texture* of SL+ or heavier). Aeolian cross-bedding may be present but there is little if any evidence of other stratification or buried soils. **Arenic [AO]**

••• Soils that consist dominantly of *unconsolidated mineral materials* that are not or only slightly gravelly (<10% >2 mm). Aeolian cross-bedding may be present but there is little if any evidence of other stratification or buried soils. If the soil material is sandy (i.e. S-LS-CS, ≤10% clay) it is coherent. **Lutic [GV]**

••• Soils that consist dominantly of *unconsolidated mineral materials* that are distinct, not or only slightly gravelly (<10% >2 mm) sedimentary *layers* or buried soils but salinity is not high (EC <2 d Sm^{-1}; 1:5 H_2O). **Stratic [ER]**

••• Soils that consist dominantly of *unconsolidated mineral materials* that are gravelly (>10% >2 mm). The *gravel* may occur as distinct *layers*, or be uniformly or irregularly distributed. **Clastic [HH]**

Comment

The Hypergypsic soils normally occur as gypsum lunettes and the Hypersalic soils are most common in many of the saline playas of the arid interior of the continent. Shelly soils are widespread as coastal and near coastal dunes in southern and south-western Australia. Carbic soils are known to occur in the Sydney Basin, NSW, but are now likely to occur more widely. The Arenic Suborder mainly caters for shallow variants of siliceous dunes and sandsheets of arid Australia, and for some usually recently deposited fluvial sands and very young coastal sands such as foredunes.

Sands greater than 1.0 m deep classify as belonging to the Arenosols Order.

The Lutic soils include loamy or clayey aeolian forms common on some of the many lunettes in southern Australia, as well as other coherent soils formed on sandy, loamy or clayey fluvial deposits, or easily weathered rocks. The Stratic and Clastic soils are most common on alluvial terraces, plains and fans.

Great Groups

No Great Groups are presently proposed for the Hypergypsic, Carbic, Lutic or Stratic Suborders as data are very limited.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

Hypersalic Rudosols

- Soils in which *sulfuric material* (at least 0.15 m thick) occurs within the upper 1.5 m of the profile. Sulfuric [EV]

  Note: The Sulfuric Great Group can be replaced by the following Great Group where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *sulfuric material* (at least 0.15 m thick) occur within the upper 1.5 m of the profile. Monosulfidic-Sulfuric [IW]
- Soils in which *sulfidic materials* occur within the upper 1.5 m of the profile. Sulfidic [EU]

  Note: The Sulfidic Great Group can be replaced by the following Great Groups where appropriate evidence is available:

- Soils in which both *monosulfidic material* and *hypersulfidic material* occur within the upper 1.5 m of the profile. Monohypersulfidic [IX]
- Other soils in which *hypersulfidic material* occurs within the upper 1.5 m of the profile. Hypersulfidic [IZ]
- Soils in which both *monosulfidic material* and *hyposulfidic material* occur within the upper 1.5 m of the profile. Monohyposulfidic [JA]
- Other soils with *hyposulfidic material* within the upper 1.5 m of the profile. Hyposulfidic [JC]
- Soils with a *gypsic horizon* that occurs within the upper 0.5 m of the profile. Gypsic [BZ]
- The *major part* of the upper 0.5 m of the profile consists of materials dominated (>50%) by halite crystals. Halic [CC]

Shelly Rudosols

- Soils that directly overlie a *coquina* substrate Coquinic [JU]
- Soils that directly overlie a *calcrete pan*. Petrocalcic [DZ]
- Soils that directly overlie *hard* rock. Lithic [CZ]
- Soils that directly overlie *unconsolidated mineral materials*. Regolithic [GF]

Arenic and Leptic Rudosols

- Soils that directly overlie a *red-brown hardpan*. Duric [BJ]
- Soils that contain a *ferric horizon* and directly overlie *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Ferric-Petroferric [GE]
- Other soils that directly overlie *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Petroferric [EA]

- •• Soils that directly overlie a *calcrete pan*. Petrocalcic [DZ]
- •• Soils that directly overlie a *siliceous pan*. Silpanic [EM]
- •• Soils that directly overlie *hard* rock. Lithic [CZ]
- •• Soils that directly overlie partially weathered or decomposed rock or saprolite. Paralithic [DU]
- •• Soils in which the *major part* of the upper 1.0 m has a distinct *gritty* feel. Gritty [JQ]

Clastic Rudosols

- •• Soils in which the *gravel* consists dominantly of little-weathered *tephric materials*. Tephric [HF]
- •• Soils in which the gravelly materials contain a *ferric horizon*. Ferric [BU]
- •• Soils in which the gravelly materials contain a *bauxitic horizon*. Bauxitic [AS]
- •• Soils in which the *gravel* consists of usually unsorted material with a wide size range. It is largely colluvial mass movement debris, including scree and talus, and landslide, mudflow and creep deposits. Colluvic [HI]
- •• Soils in which the *gravel* consists dominantly of mostly rounded materials that have been transported by streams or by wave action. Fluvic [BX]
- •• Other soils in which the *unconsolidated mineral materials* are dominated by *gravel* which mostly consists of rock or mineral fragments. Lithosolic [HJ]

Comment

The Tephric soils in the Clastic Suborder are known only from some of the Pliocene to Holocene Newer Volcanics in south-western Victoria. They have not weathered sufficiently for them to be recognised as possessing *andic properties*, or to meet the requirements for the Tenosols.

In the Petrocalcic Great Group of the Leptic Suborder the *calcrete* occurs as a substrate material that may or may not be the parent material of the soil.

Subgroups

No Subgroups are yet proposed for the Shelly and Carbic Suborders. The following Subgroups will be used for the remaining Suborders where relevant.

- Soils in which the *major part* is *strongly acid*. Acidic [AI]
- Soils that are not *calcareous* and the *major part* is not *strongly acid*. Basic [AR]
- Soils that at least in some part are *calcareous*. Calcareous [BC]

Comment

In the *Calcareous* Subgroups the carbonate present is usually not pedogenic, but is in effect part of the parent material, either of aeolian or residual origin. However, in Calcarosol landscapes it is inevitable that some young alluvial deposits may contain transported pedogenic carbonate nodules, and hence soils developed on such deposits should be regarded as Rudosols rather than Calcarosols. The presence of sedimentary layering will usually be diagnostic. Small amounts of pedogenic carbonate (<10%) may occur in fissures in the parent rock or saprolite of some Leptic Rudosols.

A similar situation arises in the case of the *Calcareous* Hypergypsic soils. These usually occur on lunettes, and thus the carbonate is also of aeolian origin. Whether or not pedogenic accumulations also occur will probably depend on the age of the lunettes. If so, the soils will be more appropriately classified as Hypergypsic Calcarosols.

Family Criteria

There are obvious problems in applying the usual Family criteria to Rudosols. By definition, *A horizons* have minimal development and hence may be difficult to recognise, and in some classes the texture is set by definition, for example the Arenic Suborder is sandy. Hence it is thought better to use the term surface soil for texture and to delete the thickness criteria and not refer to any classes for subsoil texture. By definition, subsoil texture must be the same as surface soil unless the profile is stratified, in which case the situation is usually too complex to manage satisfactorily. *Gravel* content of surface soil can be usefully used for several Suborders. In general, surface soil in this context will probably be in the range of 0.1–0.2 m in thickness.

Gravel of the surface (visual estimate)

Non-gravelly	**[E]**	<2%
Slightly gravelly	**[F]**	2–<10%
Gravelly	**[G]**	10–<20%
Moderately gravelly	**[H]**	20–50%
Very gravelly	**[I]**	>50%

Surface soil texture

Sandy	**[K]**	S-LS-CS (≤10% clay)
Loamy	**[L]**	SL-L (10–20% clay)
Clay loamy	**[M]**	SCL-CL (20–35% clay)
Silty	**[N]**	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	**[O]**	LC-MC-HC (>35% clay)

Soil depth

Very shallow	**[T]**	<0.25 m
Shallow	**[U]**	0.25–<0.5 m
Moderately deep	**[V]**	0.5–<1.0 m
Deep	**[W]**	1.0–<1.5 m
Very deep	**[X]**	1.5–5 m
Giant	**[Y]**	>5 m

Water repellence of surface soil

Non water repellent	**[NR]**	Water absorbed in 10 seconds or less
Water repellent	**[WR]**	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	**[SR]**	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

Sodosols [SO]

[Pronounced So-doh-sols]

Concept

Soils with strong texture contrast between *A horizons* and *sodic B horizons* that are not *strongly acid*. Australia is noteworthy for the extent and diversity of *sodic* soils (Isbell 1995).

Definition

Soils with a *clear or abrupt textural B horizon* and in which the *major part* of the upper 0.2 m of the B2t horizon (or the *major part* of the entire B2t horizon if it is <0.2 m thick) is *sodic* and not *strongly acid*. Hydrosols and soils with strongly *subplastic* upper *B2t horizons* are excluded.

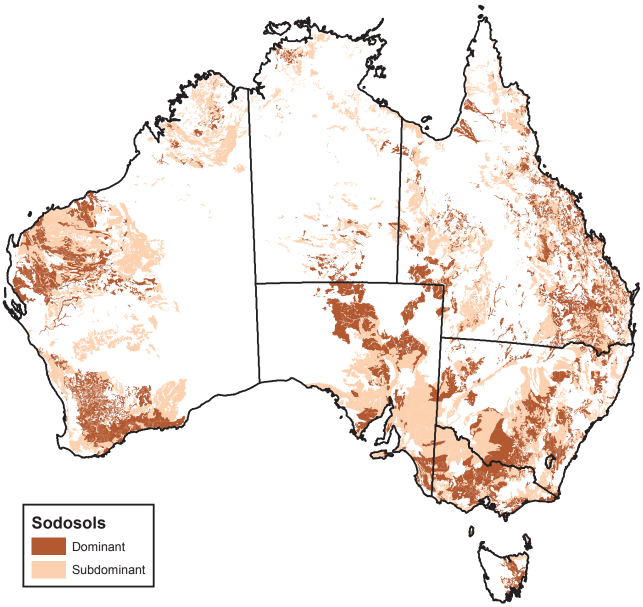
Comment

There is convincing evidence from the Riverine Plain of south-eastern Australia that soils with *sodic* clay *B horizons* (*ESP* 25–30) that are strongly *subplastic* behave very differently in terms of permeability to the more commonly found plastic *sodic* clay *B horizons* that are characterised by low to very low saturated hydraulic conductivity (McIntyre 1979). It is on this basis that *subplastic sodic* soils are excluded from Sodosols, because of their very different land use properties.

Strongly acid sodic soils are also excluded from Sodosols because they usually contain appreciable exchangeable aluminium (KCl extractable) and thus should be unlikely to disperse.

It is usually possible to assess, in the field, the likelihood of a soil possessing a *sodic* B2t horizon. Such a criterion as the presence of a bleached *A2 horizon* with an abrupt change to a B2t horizon that has columnar or prismatic structure is a useful but not universal guide. A high pH_w value (>8.5) suggests sodicity, but the converse is not true. The soapy nature of the bolus produced in field texturing will also often suggest appreciable sodium (and/or magnesium) on the clay exchange complex.

Increasing experience in many parts of Australia is confirming that the Emerson dispersion test (Emerson 1967) and the modified version of Loveday and Pyle (1973) is a reliable guide to sodicity. It can be carried out as a preliminary test in the field, but should always be repeated under the better controlled conditions of the laboratory. In the initial test at least several fragments (each



Distribution of Sodosols in Australia.

~0.2 g or ~4–5 mm diameter) are immersed in 100 ml of distilled water. The large water:soil ratio is necessary to remove any salt present in the aggregate. Also for this reason Emerson (1991) suggests that the classification for each test be made after 24 h. For the remoulded test, use a 5 mm cube that can be obtained from the bolus used for determining *field texture*. This will be approximately in the plastic limit condition. Note that distilled water should be used to prepare the bolus.

Data from Loveday and Pyle (1973) and unpublished data available to the original author Ray Isbell suggest that a dispersive soil will usually indicate sodicity (i.e. *ESP* of 6 or greater). The data of Murphy (1995) indicate that whereas Emerson class 1 and the more strongly dispersive soils of class 2 are a reliable indicator of sodicity, whereas class 3 is a more variable predictor. Emerson classes of 5 or greater or a Loveday and Pyle score of zero strongly suggest soils are non-*sodic*. There is less evidence that the dispersion tests give a reliable indication of the degree of sodicity; factors such as extent of initial slaking and initial salt content in the aggregates, and the amount of magnesium and amount and form of aluminium on the exchange complex (Emerson 1994), can also influence the rapidity of dispersion. Nevertheless, the data of Loveday and Pyle measuring dispersion after 2 h and 20 h showed that the rate of dispersion could be used as a guide to *ESP*. This relationship does not apply to the *subplastic* soils of the Riverine Plain where subsoils with an *ESP* of 25–30 do not disperse unless remoulded (Blackmore 1976). Other anomalous results occur in a small minority of normal plastic soils in which dispersion will not occur even after remoulding in spite of an *ESP* much greater than 6 and a pH_w as high as neutral. In at least some of these non-dispersive soils the typical *sodic* soil morphology is present, that is, a *conspicuously bleached A2 horizon* abruptly overlying a B2t horizon with prismatic or columnar structure, suggesting the low hydraulic conductivity expected of a *sodic B horizon*.

Suborders

The dominant colour class in the *major part* of the upper 0.2 m of the B2t horizon (or the *major part* of the entire B2t horizon if it is <0.2 m thick) is:

••• Red. Red [AA]
••• Brown. Brown [AB]
••• Yellow. Yellow [AC]
••• Grey. Grey [AD]
••• Black. Black [AE]

Great Groups

Some Great Group soils are much more common in certain colour Suborders than others. The Duric and Pedaric Great Groups are known only from the arid zone, the former being particularly widespread in Western Australia and the latter in western Queensland and New South Wales, and in South Australia.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

•• Soils with a *red-brown hardpan* either within or directly underlying the *B horizon*. Duric [BJ]

•• Soils with a *petroferric horizon* within the *solum*. Petroferric [EA]

•• Soils with a *B horizon* that is not *calcareous* and that directly overlies a *calcrete pan*. Petrocalcic [DZ]

•• Soils in which the upper 0.2 m of the B2t horizon (or the B2t horizon if it is <0.2 m thick) has a strong blocky or polyhedral structure in which average ped size is usually in the range of 5–20 mm. There is very weak adhesion between peds (when dry it is very easy to insert a spade into the upper B2t horizon). Salt contents are usually high, resulting in weak dry strength and a bulk density of ~1.3 t m^{-3} or less. In some soils the *B2t horizons* may be weakly *subplastic*. A common feature (but not diagnostic) of the overlying *A horizons* is the presence of a band of *vesicular pores* near the surface or on the underside of any surface flake. Pedaric [BK]

•• Soils with *fine earth* effervescence (1 M HCl) throughout the *solum*. Effervescent [IE]

- •• Soils in which the *major part* of the upper 0.2 m of the B2t horizon is mottled and has an *ESP* between 6 and <15. Mottled-Subnatric [FN]
- •• Other soils in which the *major part* of the upper 0.2 m of the B2t horizon has an *ESP* between 6 and <15. Subnatric [ES]
- •• Soils in which the *major part* of the upper 0.2 m of the B2t horizon is mottled and has an *ESP* between 15 and 25. Mottled-Mesonatric [FO]
- •• Other soils in which the *major part* of the upper 0.2 m of the B2t horizon has an *ESP* between 15 and 25. Mesonatric [DP]
- •• Other soils in which the *major part* of the upper 0.2 m of the B2t horizon is mottled and has an *ESP* greater than 25. Mottled-Hypernatric [FP]
- •• Other soils in which the *major part* of the upper 0.2 m of the B2t horizon has an *ESP* greater than 25. Hypernatric [CR]

Subgroups

Not every Subgroup defined below will be required or be appropriate for each Great Group of each Suborder. Some possible attributes have not been used for various reasons, for example bleaching has not been used because the great majority of soils in the class probably are bleached. Structure has not been used because of the diverse range that is encountered in these particular soils.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- Soils with a *humose horizon*. Humose [CK]
- Soils with a *melanic horizon* and a *B horizon* in which at least 0.3 m has *vertic properties*. Melanic-Vertic [DN]
- Other soils with a *melanic horizon*. Melanic [DK]
- Other soils with a *B horizon* in which at least 0.3 m has *vertic properties*. Vertic [EX]
- Soils with a *gypsic horizon* within the B or BC horizon. Gypsic [BZ]
- Soils with a *ferric horizon* within the *solum*. Ferric [BU]
- Soils with a *manganic horizon* within the *solum*. Manganic [DC]
- Soils with a *siliceous pan* in the lower A and/or upper *B horizon*. Silpanic [EM]
- Soils with an exchangeable Ca/Mg ratio of less than 0.1 in the *major part* of the B2t horizon. Magnesic [DB]

- Soils in which the *major part* of the B2t horizon is *dystrophic*.
  Dystrophic [AF]
- Soils in which the *major part* of the B2t horizon is mesotrophic.
  Mesotrophic [AG]
- Soils in which the *major part* of the B2t horizon is *eutrophic* but the *B* and *BC horizons* are not *calcareous*. **Eutrophic [AH]**
- Soils in which the carbonate is evident only as a slight to moderate effervescence (1 M HCl), and/or contain less than 2% soft finely divided carbonate, and have less than 20% *hard* carbonate nodules or concretions.
  Hypocalcic [CV]
- Soils with a *calcareous horizon* containing more than 50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. **Lithocalcic [DA]**
- Soils with a *calcareous horizon* containing 20–50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions and/or carbonate-coated *gravel*. **Supracalcic [FB]**
- Soils with a *calcareous horizon* containing more than 20% of mainly soft, finely divided carbonate, and 0–20% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions, and/or carbonate-coated *gravel*.
  Hypercalcic [CQ]
- Other soils with a *calcareous horizon*. (See *carbonate classes* in glossary.)
  Calcic [BD]

Comment

The *calcareous* classes above approximately correspond to those of Wetherby and Oades (1975) as follows: Hypocalcic – Class IV, Lithocalcic – Class III B and III C, Supracalcic – Class III B, Hypercalcic – Class III A, Calcic – Class I and IIIA. In the Lithocalcic and Supracalcic classes the coarse fragments may be >0.2 m in size and soft carbonate may or may not be present.

Family Criteria

A horizon thickness

Thin	[A]	<0.1 m
Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

Gravel of the surface and *A1 horizon*

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

A1 horizon texture

Peaty	[J]	Dominated by *organic materials*
Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)

B horizon maximum texture[14]

Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

Soil depth

Very shallow	[T]	<0.25 m
Shallow	[U]	0.25–<0.5 m
Moderately deep	[V]	0.5–<1.0 m
Deep	[W]	1.0–<1.5 m
Very deep	[X]	1.5–5 m
Giant	[Y]	>5 m

Water repellence of surface soil

Non water repellent	[NR]	Water absorbed in 10 seconds or less
Water repellent	[WR]	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	[SR]	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

[14] This refers to the most clayey field texture category.

Tenosols [TE]

[Pronounced Ten-oh-sols]

Concept

This Order is designed to embrace soils with generally only weak *pedologic organisation* apart from the *A horizons*, excluding soils that have deep sandy profiles with a *field texture* of sand, loamy sand or clayey sand in 80% or more of the upper 1.0 m. It encompasses a rather diverse range of soils that occur in many parts of Australia.

Definition

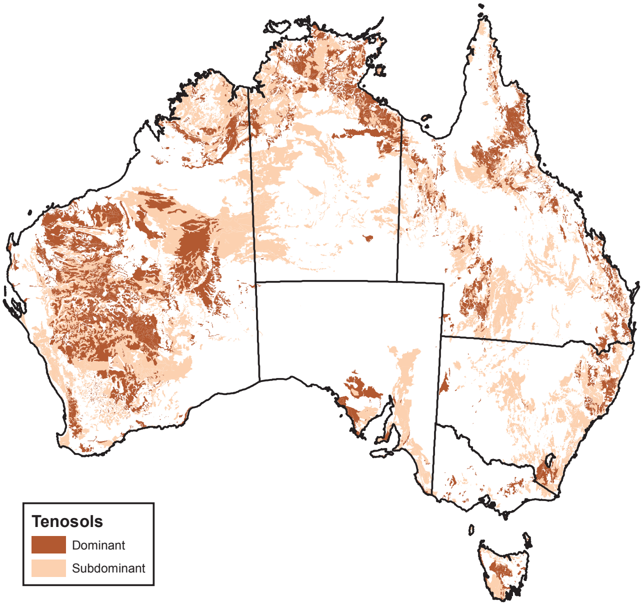
Soils that do not fit the requirements of any other Orders and generally with one or more of the following:

1. A *peaty horizon*.
2. A humose, melacic or *melanic horizon*, or *conspicuously bleached A2 horizon*, that overlies a *calcrete pan*, *hard* unweathered rock or other *hard* materials; or partially weathered or decomposed rock or saprolite, or *unconsolidated mineral materials*.
3. *A horizons* that meet all the conditions for a *peaty*, *humose*, *melacic* or *melanic horizon* except the depth requirement, and directly overlie a *calcrete pan*, *hard* unweathered rock or other *hard* materials; or partially weathered or decomposed rock or saprolite, or *unconsolidated mineral materials*.
4. *A1 horizons* that have more than a weak development of structure and directly overlie a *calcrete pan*, *hard* unweathered rock or other *hard* materials; or partially weathered or decomposed rock or saprolite, or *unconsolidated mineral materials*.
5. An *A2 horizon* that overlies a *calcrete pan*, *hard* unweathered rock or other *hard* materials; or partially weathered or decomposed rock or saprolite, or *unconsolidated mineral materials*.
6. A *B2 horizon* with 15% clay (SL) or less,[15] or a transitional horizon (C/B) occurring in fissures in the parent rock or saprolite that contains

[15] This means that a strongly developed B2w horizon, in terms of colour development, is allowed in Tenosols provided the clay content does not exceed 15%.

between 10 and 50% of *B horizon* material (including pedogenic carbonate).

7. A ferric or *bauxitic horizon* >0.2 m thick.
8. A *calcareous horizon* >0.2 m thick.



Distribution of Tenosols in Australia.

Comment

It may be desirable to specify a minimum thickness for those *A1 horizons* that do not meet the requirements for a *peaty*, *humose*, *melacic* or *melanic horizon*. The inclusion of certain soils with *conspicuously bleached A2 horizons* may be questioned by some, but it is difficult to find a more appropriate place for them.

The Tenosols will differ from Rudosols by virtue of having either a more than *weakly developed* A1 horizon, an A2, or a *weakly developed B horizon*. As *B horizons* are difficult to identify consistently in some Tenosols, specific mention of a *B horizon* is omitted from some Suborders. They will obviously grade to Kandosols, and some difficulty may be experienced in separating medium-textured Tenosols from Kandosols. Here again, *B horizon* development is the key; Kandosols must have a clearly distinguishable, well developed *B2 horizon* with more than 15% clay. Tenosols will grade to Podosols, but the latter must have a Podosol diagnostic *B horizon*.

Tenosols also grade to Arenosols but lack the deep sandy *horizons* characteristic of this Order.

In cold, wet environments, some Tenosols with peaty *A horizons* will grade to Organosols.

This third edition of the *Australian Soil Classification* removes the Orthic term from the bleached and colour Suborders.

Suborders

••• Soils with a *peaty*, *humose*, *melacic* or *melanic horizon*, and are underlain within 0.5 m of the surface by a *calcrete pan*; *hard* unweathered rock or other *hard* materials; or partially weathered or decomposed rock or saprolite. An unbleached *A2 horizon* may be present between the dark surface *horizons* and the substrate material. Chernic-Leptic [BF]

••• Other soils with a *peaty*, *humose*, *melacic* or *melanic horizon*. A *conspicuously bleached A2 horizon* is not present. Chernic [BE]

••• Soils with a ferric or *bauxitic horizon* (nodules or concretions) that is at least 0.2 m thick and occupies >50% of the *solum* depth. The *solum* depth excludes cemented *layers*. Genetically these soils may be closely related to Podosols. Sesqui-Nodular [IL]

••• Soils with a *horizon* containing more than 20% of *fine earth* carbonate that is at least 0.2 m thick. Calcenic [IM]

••• Soils with a *conspicuously bleached A2 horizon*, and are underlain within 0.5 m of the surface by a *calcrete pan*; *hard* unweathered rock or other *hard* materials; or partially weathered or decomposed rock or saprolite. Bleached-Leptic [AW]

••• Other soils that are underlain within 0.5 m of the surface by a *calcrete pan*; *hard* unweathered rock or other *hard* materials; or partially weathered or decomposed rock or saprolite. Leptic [CY]

••• Other soils with a *conspicuously bleached A2 horizon*. Bleached [AT]

The dominant colour class in the *major part* of the upper 0.5 m of the profile (or the entire profile if it is <0.5 m thick) is:

••• Red. Red [AA]
••• Brown. Brown [AB]
••• Yellow. Yellow [AC]
••• Grey. Grey [AD]
••• Black. Black [AE]

Great Groups

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

Chernic-Leptic and Leptic Tenosols

- •• Soils that overlie a *red-brown hardpan*. Duric [BJ]
- •• Soils that contains a *ferric horizon* and directly overlies *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Ferric-Petroferric [GE]
- •• Other soils that overlie *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Petroferric [EA]
- •• Soils that overlie a *siliceous pan*. Silpanic [EM]
- •• Soils that overlie a *calcrete pan*. Petrocalcic [DZ]
- •• Soils that overlie *hard* rock. Lithic [CZ]
- •• Soils that overlie partially weathered or decomposed rock or saprolite. Paralithic [DU]

Chernic Tenosols

- •• Soils that overlie *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Petroferric [EA]
- •• Soils that overlie a *siliceous pan*. Silpanic [EM]
- •• Soils that overlie a *calcrete pan*. Petrocalcic [DZ]
- •• Soils with a *thin ironpan*. Placic [EC]
- •• Soils that have *andic properties* and has formed in basaltic *tephric materials* that may be visibly stratified. Andic [AK]
- •• Other soils that have formed in *tephric materials* that may be visibly stratified. Tephric [HF]
- •• Soils with a *bauxitic horizon*. Bauxitic [AS]
- •• Other soils with a *ferric horizon*. Ferric [BU]
- •• Soils with a transitional horizon (C/B) occurring in fissures in the parent rock or saprolite that contains between 10 and 50% of *B horizon* material (including pedogenic carbonate). Inceptic [IA]
- •• Soils that overlie *hard* rock. Lithic [CZ]
- •• Soils that overlie partially weathered or decomposed rock or saprolite. Paralithic [DU]
- •• Soils that overlie *marl*. Marly [DD]
- •• Soils that overlie other *unconsolidated mineral materials*. Regolithic [GF]

Sesqui-Nodular Tenosols

- •• Soils that overlie a *red-brown hardpan*. Duric [BJ]

- Soils that overlie *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Petroferric [EA]
- Soils that overlie a *reticulate horizon*. Reticulate [EF]
- Soils that overlie a *siliceous pan*. Silpanic [EM]
- Soils that overlie a *calcrete pan*. Petrocalcic [DZ]
- Soils with an *argic horizon* within the *solum*. Argic [AP]
- Soils with a transitional horizon (C/B) occurring in fissures in the parent rock or saprolite that contains between 10 and 50% of *B horizon* material (including pedogenic carbonate). Inceptic [IA]
- Soils that overlie *hard* rock. Lithic [CZ]
- Soils that overlie partially weathered or decomposed rock or saprolite. Paralithic [DU]
- Soils that overlie other *unconsolidated mineral materials*. Regolithic [GF]

Calcenic Tenosols

- Soils that overlie a *red-brown hardpan*. Duric [BJ]
- Soils that overlie a *siliceous pan*. Silpanic [EM]
- Soils that overlie a *calcrete pan*. Petrocalcic [DZ]
- Soils with a *ferric horizon* within the *solum*. Ferric [BU]
- Soils that have *andic properties* and has formed in basaltic *tephric materials* that may be visibly stratified. Andic [AK]
- Other soils that have formed in *tephric materials* that may be visibly stratified. Tephric [HF]
- Soils with an *argic horizon* within the *solum*. Argic [AP]
- Soils in which the profile is not or only slightly gravelly (2 mm) throughout, the soil material is either loose or only weakly coherent both moist and dry, may have aeolian cross-bedding, and the texture is dominantly sandy (i.e. *field textures* of S-LS-CS) in >80% of the profile and no *layer* with a clay content of >15% (i.e. *field texture* of SL+). Arenic [AO]
- Soils that overlie *hard* rock. Lithic [CZ]
- Soils that overlie partially weathered or decomposed rock or saprolite. Paralithic [DU]
- Soils that overlie other *unconsolidated mineral materials*. Regolithic [GF]

Bleached-Leptic Tenosols

- •• Soils that contains a *ferric horizon* and directly overlies *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Ferric-Petroferric [GE]
- •• Other soils that overlie *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Petroferric [EA]
- •• Soils in which the *major part* of the upper 1.0 m has a distinct *gritty* feel and overlies a *siliceous pan*. Gritty-Silpanic [JV]
- •• Soils that overlie a *siliceous pan*. Silpanic [EM]
- •• Soils that overlie a *calcrete pan*. Petrocalcic [DZ]
- •• Soils in which the *A2 horizon* contains or overlies a *ferric horizon*. Ferric [BU]
- •• Soils in which the *major part* of the upper 1.0 m has a distinct *gritty* feel and overlies *hard* rock. Gritty-Lithic [JW]
- •• Other soils that overlie *hard* rock. Lithic [CZ]
- •• Soils in which the *major part* of the upper 1.0 m has a distinct *gritty* feel and overlies partially weathered or decomposed rock or saprolite. Gritty-Paralithic [JX]
- •• Other soils that overlie partially weathered or decomposed rock or saprolite. Paralithic [DU]

Bleached, Yellow, Red, Brown, Grey and Black Tenosols

- •• Soils that have a *ferric horizon* and overlies a *red-brown hardpan*. Ferric-Duric [FK]
- •• Other soils that overlie a *red-brown hardpan*. Duric [BJ]
- •• Soils that contain a *ferric horizon* and directly overlies *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Ferric-Petroferric [GE]
- •• Other soils that overlie *ferricrete*, a *petroferric horizon* or a *petroreticulate horizon*. Petroferric [EA]
- •• Soils that overlie a *siliceous pan*. Silpanic [EM]
- •• Soils that overlie a *calcrete pan*. Petrocalcic [DZ]
- •• Soils that contain a *ferric horizon* and which overlie a *reticulate horizon*. Ferric-Reticulate [IS]
- •• Soils that overlie a *reticulate horizon*. Reticulate [EF]
- •• Other soils with a *ferric horizon*. Ferric [BU]
- •• Soils with a *bauxitic horizon*. Bauxitic [AS]

- •• Soils that have *andic properties* and has formed in basaltic *tephric materials* that may be visibly stratified. Andic [AK]
- •• Other soils that have formed in *tephric materials* that may be visibly stratified. Tephric [HF]
- •• Soils with an *argic horizon*. Argic [AP]
- •• Soils in which the profile is not or only slightly gravelly (2 mm) throughout, the soil material is either loose or only weakly coherent both moist and dry, may have aeolian cross-bedding, and the texture is dominantly sandy (i.e. *field textures* of S-LS-CS) in >80% of the profile and no *layer* with a clay content of >15% (i.e. *field texture* of SL+). Arenic [AO]
- •• Soils with a transitional horizon (C/B) occurring in fissures in the parent rock or saprolite that contains between 10 and 50% of *B horizon* material (including pedogenic carbonate). Inceptic [IA]
- •• Soils in which the *major part* of the upper 1.0 m has a distinct *gritty* feel and overlies *hard* rock. Gritty-Lithic [JW]
- •• Other soils that overlie *hard* rock. Lithic [CZ]
- •• Soils in which the *major part* of the upper 1.0 m has a distinct *gritty* feel and overlies partially weathered or decomposed rock or saprolite. Gritty-Paralithic [JX]
- •• Other soils that overlie partially weathered or decomposed rock or saprolite. Paralithic [DU]
- •• Soils that overlie *marl*. Marly [DD]
- •• Soils in which the *major part* of the upper 1.0 m has a distinct *gritty* feel. Gritty [JQ]
- •• Soils in which the *B horizon* directly overlies other *unconsolidated mineral materials*. Regolithic [GF]

Subgroups

These have been grouped into the various Suborders, but not all Subgroups will be appropriate for each Great Group of a particular Suborder.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

Subgroups of Chernic-Leptic Tenosols

- Soils with a *peaty horizon*. Peaty [DW]
- Soils with a *humose horizon*. Humose [CK]

- Soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon*. Melanic [DK]

Subgroups of Chernic Tenosols

- Soils with a *peaty horizon*. Peaty [DW]
- Soils with a *humose horizon* and the *major part* of the *B horizon* (if present) is *strongly acid*. Humose-Acidic [GY]
- Soils with a *humose horizon* and at least some part of the B, BC or C/*B horizon* (if present) is *calcareous*. Humose-Calcareous [GU]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon* and the *major part* of the *B horizon* (if present) is not *strongly acid* but the B and BC or C/*B horizons* are not *calcareous*. Melacic-Basic [FU]
- Other soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon* and the *major part* of the *B horizon* (if present) is *strongly acid*. Melanic-Acidic [FV]
- Soils with a *melanic horizon* and at least some part of the B, BC or C/*B horizon* (if present) is *calcareous*. Melanic-Calcareous [FC]
- Other soils with a *melanic horizon*. Melanic [DK]

Subgroups of Sesqui-Nodular Tenosols

- Soils with a *conspicuously bleached A2 horizon* and a *manganic horizon* within the *solum*. Bleached-Manganic [AY]
- Other soils with a *manganic horizon* with the *solum*. Manganic [DC]
- Other soils with a *conspicuously bleached A2 horizon*. Bleached [AT]
- Soils in which the *major part* of the *solum* is *strongly acid*. Acidic [AI]
- Soils in which the *major part* of the *solum* is not *strongly acid* and no part of the *solum* is *calcareous*. Basic [AR]
- Other soils in which at least some part of the *solum* is *calcareous*. Calcareous [BC]

Subgroups of Calcenic Tenosols

- Soils in which the *calcareous horizon* contains more than 50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions. Lithocalcic [DA]
- Soils in which the *calcareous horizon* contains 20–50% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions. Supracalcic [FB]

- Other soils in which the *calcareous horizon* contains less than 20% of *hard*, *calcrete* fragments and/or carbonate nodules or concretions. Hypercalcic [CQ]

Subgroups of Bleached-Leptic Tenosols

- Soils with a *peaty horizon*. Peaty [DW]
- Soils with a *humose horizon* and the *major part* of the *A2 horizon* is strongly acid. Humose-Acidic [GY]
- Soils with a *humose horizon* and at least some part of the *A2 horizon* is *calcareous*. Humose-Calcareous [GU]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon* and the *major part* of the *A2 horizon* is not *strongly acid*. Melacic-Basic [FU]
- Other soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon* and the *major part* of the *A2 horizon* is *strongly acid*. Melanic-Acidic [FV]
- Soils with a *melanic horizon* and at least some part of the *A2 horizon* is *calcareous*. Melanic-Calcareous [FC]
- Other soils with a *melanic horizon*. Melanic [DK]
- Soils in which the *major part* of the *A2 horizon* is *strongly acid*. Acidic [AI]
- Other soils in which the *major part* of the *A2 horizon* is not *strongly acid* but the *A2 horizon* is not *calcareous*. Basic [AR]
- Other soils in which at least some part of the *A2 horizon* is *calcareous*. Calcareous [BC]

Subgroups of Leptic Tenosols

- Soils with all the requirements for a *peaty horizon* except the thickness. Subpeaty [ID]
- Soils with all the requirements of a *humose horizon* except the thickness. Subhumose [DR]
- Soils with all the requirements of a *melacic horizon* except the thickness. Submelacic [FF]
- Soils with all the requirements of a *melanic horizon* except the thickness. Submelanic [FG]
- Soils in which the *major part* of the *solum* is *strongly acid*. Acidic [AI]

- Soils in which the *major part* of the *solum* is not *strongly acid* and no part of the *solum* is *calcareous*. Basic [AR]
- Other soils in which at least some part of the *solum* is *calcareous*. Calcareous [BC]

Subgroups of Bleached, Red, Brown, Yellow, Grey and Black Tenosols

- Soils with a *peaty horizon*. Peaty [DW]
- Soils with a *humose horizon* and the *major part* of the *A2 horizon* is *strongly acid*. Humose-Acidic [GY]
- Soils with a *humose horizon* and at least some part of the *A2 horizon* is *calcareous*. Humose-Calcareous [GU]
- Other soils with a *humose horizon*. Humose [CK]
- Soils with a *melacic horizon* and the *major part* of the *A2 horizon* is not *strongly acid*. Melacic-Basic [FU]
- Other soils with a *melacic horizon*. Melacic [DG]
- Soils with a *melanic horizon* and the *major part* of the *A2 horizon* is *strongly acid*. Melanic-Acidic [FV]
- Soils with a *melanic horizon* and at least some part of the *A2 horizon* is *calcareous*. Melanic-Calcareous [FC]
- Other soils with a *melanic horizon*. Melanic [DK]
- Soils with a *manganic horizon* with the *solum*. Manganic [DC]
- Soils in which the *major part* of the *solum* is *strongly acid*. Acidic [AI]
- Other soils in which the *major part* of the *solum* is not *strongly acid* but the *A2 horizon* is not *calcareous*. Basic [AR]
- Other soils in which at least some part of the *solum* is *calcareous*. Calcareous [BC]

Family Criteria

Note that in some Suborders the *soil depth* may be the same as *A1 horizon* thickness. In those Suborders it will not be relevant to record maximum *B horizon* texture.

A1 horizon thickness plus the thickness of organic horizons (O2, P1 or P2) if present

Thin	[A]	<0.1 m
Moderately thick	[B]	0.1–<0.3 m
Thick	[C]	0.3–0.6 m
Very thick	[D]	>0.6 m

Gravel of the surface and *A1 horizon*

Non-gravelly	[E]	<2%
Slightly gravelly	[F]	2–<10%
Gravelly	[G]	10–<20%
Moderately gravelly	[H]	20–50%
Very gravelly	[I]	>50%

A1 horizon texture or the texture of organic horizons (O2, P1 or P2) if present

Peaty	[J]	Dominated by *organic materials*
Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

B horizon maximum texture[16]

Sandy	[K]	S-LS-CS (≤10% clay)
Loamy	[L]	SL-L (10–20% clay)
Clay loamy	[M]	SCL-CL (20–35% clay)
Silty	[N]	ZL-ZCL (25–35% clay and silt 25% or more)
Clayey	[O]	LC-MC-HC (>35% clay)

[16] This refers to the most clayey field texture category. This may include a transitional C/B horizon.

Soil depth

Very shallow	**[T]**	<0.25 m
Shallow	**[U]**	0.25–<0.5 m
Moderately deep	**[V]**	0.5–<1.0 m
Deep	**[W]**	1.0–<1.5 m
Very deep	**[X]**	1.5–5 m
Giant	**[Y]**	>5 m

Water repellence of surface soil

Non water repellent	**[NR]**	Water absorbed in 10 seconds or less
Water repellent	**[WR]**	Water takes more than 10 seconds and 2 Molar ethanol takes 10 seconds or less to be absorbed into soil
Strongly water repellent	**[SR]**	2 Molar ethanol takes more than 10 seconds to be absorbed into soil

Vertosols [VE]

[Pronounced Vert-oh-sols]

Concept

Clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth have *slickensides and/or lenticular peds*. Although many soils exhibit gilgai microrelief, this feature is not used in their definition. Australia has the greatest area and diversity of cracking clay soils of any country in the world.

Definition

Soils with all of the following:

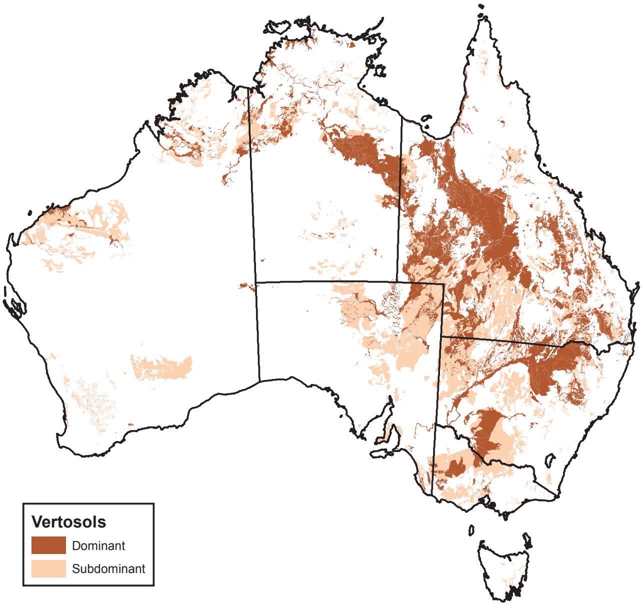
1. A clay *field texture* or 35% or more clay throughout the *solum* except for thin, surface crusty *horizons* 30 mm or less thick, and
2. When dry, open cracks occur at some time in most years.[17] These are at least 5 mm wide and extend upward to the surface or to the base of any plough *layer*, *peaty horizon*, self-mulching horizon, or thin, surface crusty horizon, and
3. *Slickensides and/or lenticular peds* occur at some depth in the *solum*. See Comment below.

Comment

In some clay soils it may be difficult to decide if sufficient cracks are present, or at the time of inspection the soil may be too moist to exhibit cracking. Also, in arid zone clay soils that commonly have high salt contents, the soil structure may be so fine and strong granular, or 'puffy', that it is difficult to decide if cracks are present or not. In such soils it is also obviously difficult to discern *slickensides and/or lenticular peds*. In yet other clay soils (≤50% clay or more) cracks may develop but *slickensides and/or lenticular peds* are apparently not present.

Because cracking, *slickensides and/or lenticular peds* are essentially used as evidence to indicate shrink-swell behaviour, it is desirable that surrogate measurements be available if the morphological evidence is lacking or cannot be determined. See *Vertic properties*.

[17] Note that there is no crack frequency criterion as in the Factual Key (Northcote 1979)



Distribution of Vertosols in Australia.

Suborders

- ••• Soils with stagnant water on the soil surface and/or saturation of some part of the upper 0.5 m more or less continuously for prolonged periods in most years. The length of a 'prolonged period' is probably in the order of 2–3 continuous months. Evidence of wetness may be indicated by the presence of mottling and *gley colours* (chroma of 2 or less). Aquic [AM]

The dominant colour class in the *major part* of the upper 0.5 m of the *B2 horizon* (or the *major part* of the entire *B2 horizon* if it is <0.5 m thick) is:

- ••• Red. Red [AA]
- ••• Brown. Brown [AB]
- ••• Yellow. Yellow [AC]
- ••• Grey. Grey [AD]
- ••• Black. Black [AE]

Comment

Of the soils entered in the database for the first edition, the most common class was Black (40%) which is probably a reflection of the agricultural importance of these soils.

Great Groups

These may not all apply to each Suborder, in particular our knowledge of the Aquic Suborder is limited.

- Soils with a surface that is moderately to strongly self-mulching; when the soil is dry the self-mulching *layer* should be at least 10 mm thick. Initial drying may form a thin (2–3 mm) surface flake that readily disintegrates to a mulch on further drying. This process is accelerated by mechanical disturbance. Self-mulching [EI]
- Soils with a pedal (stronger than weak grade, blocky or polyhedral) *A horizon* that is either not or only weakly self-mulching, and there is no surface crusty horizon. Some soils after wetting and drying may form a thin 5–10 mm surface flake that cracks into irregular polygons (plates) 30–100 mm diameter. These may be readily separated and removed from the underlying pedal clay. Epipedal [GS]
- Soils with a massive or weakly structured surface crusty horizon 30 mm or less thick, often of lighter texture (lower clay content) than the underlying pedal clay (blocky or polyhedral) that is not self-mulching. Crusty [BH]
- Soils with a massive or weak blocky (usually >50 mm peds) *A horizon*, and there is no surface crusty horizon. Massive [DF]
- Soils with a surface *peaty horizon*. Peaty [DW]

Comment

Apart from the Peaty forms, each of the above soil surface conditions tends to reform despite cultivation or surface trampling. There may be a problem in identifying the self-mulching condition in periods of initial drying (i.e. in assessing the stability of the surface flake that forms following rainfall). If there is doubt as to whether a soil is self-mulching or has only a pedal surface, it is suggested that the latter condition be recorded (i.e. use the self-mulching Great Group only for those soils where the condition is not in doubt). It may be difficult to determine the surface condition if a dense grass sward is present. In this situation it will be necessary to look for a patch of bare ground, or even to kill the grass with herbicide and return at a later date. Note also that large soil units bounded by cracks are not considered to be coarse peds. It is usually necessary to examine these soils in the moist state to determine their degree of pedality.

Subgroups

It is thought that the following Subgroups will be required for most of the Suborders and Great Groups. Note that some of the differentiating criteria are not mutually exclusive, and thus sometimes it has been a subjective decision as to which attributes have priority in the key.

If a diagnostic feature in the key begins more than 1.5 m from the soil surface it may not have a significant impact on the performance of the soil. Refer to *diagnostic features* in the glossary for guidance on the use of such features in the classification.

- Soils with a seasonal saline water table present in the upper 0.5 m of the profile (water conductivity >2 dS m^{-1}). Salt efflorescence may occur on the surface soil when dry. Salic [EG]
- Soils in which *sulfuric material* (at least 0.15 m thick) occurs within the upper 1.5 m of the profile. Sulfuric [EV]

  Note: The Sulfuric Subgroup can be replaced by the following Subgroup where appropriate evidence is available:
- Soils in which both *monosulfidic material* and *sulfuric material* (at least 0.15 m thick) occur within the upper 1.5 m of the profile. Monosulfidic-Sulfuric [IW]
- Soils in which *sulfidic materials* occur within the upper 1.5 m of the profile. Sulfidic [EU]

  Note: The Sulfidic Subgroup can be replaced by the following Subgroups where appropriate evidence is available:
- Soils in which both *monosulfidic material* and *hypersulfidic material* occur within the upper 1.5 m of the profile. Monohypersulfidic [IX]
- Other soils in which *hypersulfidic material* occurs within the upper 1.5 m of the profile. Hypersulfidic [IZ]
- Soils in which both *monosulfidic material* and *hyposulfidic material* occur within the upper 1.5 m of the profile. Monohyposulfidic [JA]
- Other soils with *hyposulfidic material* within the upper 1.5 m of the profile. Hyposulfidic [JC]
- Soils with a *red-brown hardpan* either within or directly underlying the *B horizon*. Duric [BJ]
- Soils in which the *B horizon* directly overlies a *calcrete pan*. Petrocalcic [DZ]
- Soils in which the upper 0.1 m of the *solum* is *sodic* and a *gypsic horizon* is present within the B or BC horizon. Episodic-Gypsic [GQ]
- Other soils with a *gypsic horizon* within the B or BC horizon. Gypsic [BZ]
- Soils in which the upper 0.1 m of the *solum* is *sodic* and the *major part* of the upper 0.5 m of the *solum* is *strongly acid*. Episodic-Epiacidic [EP]
- Soils in which the upper 0.1 m of the *solum* is *sodic* and the *major part* of the *solum* below 0.5 m is *strongly acid*. Episodic-Endoacidic [GG]
- Soils in which the upper 0.1 m of the *solum* is *sodic* and the *major part* of the upper 0.5 m of the *solum* is *calcareous*. Episodic-Epicalcareous [GH]
- Soils in which the upper 0.1 m of the *solum* is *sodic* and the *major part* of the *solum* below 0.5 m is *calcareous*. Episodic-Endocalcareous [GI]

- Other soils in which the upper 0.1 m of the *solum* is *sodic*. Episodic [BN]
- Soils in which some subsurface horizon within the upper 0.5 m of the *solum* has an *ESP* of 15 or greater and the *major part* of the upper 0.5 m of the *solum* is *strongly acid*. Epihypersodic-Epiacidic [CU]
- Soils in which some subsurface horizon within the upper 0.5 m of the *solum* has an *ESP* of 15 or greater and the *major part* of the *solum* below 0.5 m is *strongly acid*. Epihypersodic-Endoacidic [GN]
- Soils in which the *major part* of the upper 0.5 m of the *solum* is *strongly acid* and mottled. Epiacidic-Mottled [GK]
- Other soils in which the *major part* of the upper 0.5 m of the *solum* is *strongly acid*. Epiacidic [GA]
- Soils in which the *major part* of the upper 0.5 m of the *solum* is *calcareous* and the *major part* of the *solum* below 0.5 m is *strongly acid*. Epicalcareous-Endoacidic [GJ]
- Soils in which the *major part* of the upper 0.5 m of the *solum* is *calcareous* and some subsurface horizon within this depth has an *ESP* of 15 or greater. Epicalcareous-Epihypersodic [FM]
- Soils in which some subsurface horizon within the upper 0.5 m of the *solum* has an *ESP* of 15 or greater and the *major part* of the *solum* below 0.5 m is *calcareous*. Epihypersodic-Endocalcareous [GO]
- Other soils in which some subsurface horizon within the upper 0.5 m of the *solum* has an *ESP* of 15 or greater. Epihypersodic [BR]
- Soils in which the *major part* of the upper 0.5 m of the *solum* is *calcareous* and an *ESP* of 15 or greater occurs in some subhorizon of the *solum* below 0.5 m. Epicalcareous-Endohypersodic [GB]
- Other soils in which the *major part* of the upper 0.5 m of the *solum* is *calcareous*. Epicalcareous [FY]
- Soils in which the *major part* of the *solum* below 0.5 m is *strongly acid* and mottled. Endoacidic-Mottled [GL]
- Other soils in which the *major part* of the *solum* below 0.5 m is *strongly acid*. Endoacidic [BL]
- Soils in which the *major part* of the *solum* below 0.5 m is *calcareous* and some subhorizon of the *solum* below 0.5 m has an *ESP* of 15 or greater. Endocalcareous-Endohypersodic [GM]
- Soils with a *ferric horizon* within the *solum*, and in which the *major part* of the *solum* below 0.5 m has an *ESP* of 15 or greater. Ferric-Endohypersodic [JF]

- Soils with a *manganic horizon* within the *solum*, and in which the *major part* of the *solum* below 0.5 m has an *ESP* of 15 or greater. Manganic-Endohypersodic [JG]
- Other soils in which some subhorizon of the *solum* below 0.5 m has an *ESP* of 15 or greater. Endohypersodic [BP]
- Other soils with a *ferric horizon* within the *solum*, and in which the *major part* of the *solum* below 0.5 m is *calcareous*. Ferric-Endocalcareous [JH]
- Soils with a *manganic horizon* within the *solum*, and in which the *major part* of the *solum* below 0.5 m is *calcareous*. Manganic-Endocalcareous [JI]
- Soils in which the *major part* of the *solum* below 0.5 m is *calcareous* and the *major part* of the upper 0.5 m of the *solum* is mottled. Endocalcareous-Mottled [HE]
- Other soils in which the *major part* of the *solum* below 0.5 m is *calcareous*. Endocalcareous [FZ]
- Soils in which the *major part* of the *B horizon* has an exchangeable Ca/Mg ratio of less than 0.1. Magnesic [DB]
- Soils with a *conspicuously bleached A2 horizon*. Bleached [AT]
- Other soils with a *ferric horizon* within the *solum*. Ferric [BU]
- Soils with a *manganic horizon* within the *solum*. Manganic [DC]
- Soils in which the *major part* of the upper 0.5 m of the *solum* is mottled. Mottled [DQ]
- Other soils in which the *major part* of the upper 0.5 m of the *solum* is whole coloured. Haplic [CD]

Comment

It should be noted that all the Endoacidic soils classified are also Endohypersodic, with some also being Epihypersodic. Additionally, some Epicalcareous-Epihypersodic soils are Endoacidic at depth. It is not possible to cater for all these combinations.

Family Criteria

Because of the uniform clayey nature of these soils and their usual lack of distinct horizonation, several of the usual Family criteria are not appropriate for Vertosols. *Field texture* in these soils may not be a reliable guide to actual clay content (see *Field Handbook*), and it may also be difficult to achieve consistent results between operators. Hence it is thought more appropriate to provide for a subdivision of actual clay content as determined by laboratory analysis. The classes used are similar to those used for clayey particle-size classes in *Soil Taxonomy* (Soil Survey Staff 2014). Other criteria used are *gravel* content of surface and A1 horizon and *soil depth*.

Gravel* of the surface and *A1 horizon

Non-gravelly	**[E]**	<2%
Slightly gravelly	**[F]**	2–<10%
Gravelly	**[G]**	10–<20%
Moderately gravelly	**[H]**	20–50%
Very gravelly	**[I]**	>50%

Clay content of upper 0.1 m (excluding any crusty horizon)

Fine	**[Q]**	<45% clay
Medium fine	**[R]**	<45–60% clay
Very fine	**[S]**	>60% clay

***B horizon* maximum clay content**

Fine	**[Q]**	<45% clay
Medium fine	**[R]**	<45–60% clay
Very fine	**[S]**	>60% clay

Soil depth

Very shallow	**[T]**	<0.25 m
Shallow	**[U]**	0.25–<0.5 m
Moderately deep	**[V]**	0.5–<1.0 m
Deep	**[W]**	1.0–<1.5 m
Very deep	**[X]**	1.5–5 m
Giant	**[Y]**	>5 m

Glossary

This glossary does not attempt to define all morphological terms used in the classification. It mainly deals with those that are not defined in the *Australian Soil and Land Survey Field Handbook* (NCST 2009). As the *Field Handbook* is currently being revised, some definitions in the glossary are aligned with the new *Field Handbook* rather than the current (third) edition.

Within this glossary, and throughout this publication, the *Australian Soil and Land Survey Field Handbook* is referred to as the *Field Handbook* (the *Field Handbook* is also colloquially known as the Yellow book due to the colour of its cover).

For clarity in this publication the levels in the classification are capitalised – for example Order, Suborder, Great Group, Subgroup and Family. This is not a requirement when using these terms outside of this publication.

A horizons

A1 horizon
Mineral horizon at or near the soil surface with some accumulation of humified organic matter. Usually darker than underlying horizon/s.

A2 horizon
Mineral horizon below the A1 horizon having, either alone or in combination, less organic matter, sesquioxides, or silicate clay than immediately adjacent horizons. Usually paler than adjacent horizons.

Conspicuously bleached A2 horizon
80% or more of the horizon is bleached. Bleached horizons are defined in terms of Munsell Soil Color notation for dry soil (Munsell Color 2010). For all hues – a value of 7 or greater and a chroma of 4 or less. Where adjacent horizons have hues of 5YR or redder – a value of 6 or greater with a chroma of 4 or less.

Ap horizon
A horizon/s where ploughing or other disturbance by humans has occurred.

Refer to the *Field Handbook* for further information.

Andic properties

These occur in soils that contain significant amounts of volcanic glass and short-range-order minerals such as allophane. Chemical tests and *Soil Taxonomy* requirements are given in Soil Survey Staff (2014).

Argic horizon

An argic horizon is a subsoil horizon(s) consisting of distinct lamellae, usually 5–10 mm thick but occasionally up to 100 mm or greater. They occur as sharply defined, horizontal to subhorizontal layers that are appreciably more clayey than the adjacent sandy or sandy loam soil material. There may be one or several layers present. Consistence strength is stronger, and colour is usually darker and redder or browner than the adjacent soil. This use of the term 'argic' varies from its use in the *World Reference Base* (2015). The most commonly known occurrences are in the mallee dune landscapes of Victoria–South Australia.

Ash material

The typically grey, orange, red or black material that remains after the burning of organic materials, for example P horizons (peat) or O horizons (organic debris). In some cases, humose soil material with >10% organic carbon may also ignite to produce ash material. Ash material may occur on the surface, or as one or more layers in soil horizons or distributed along former root channels.

B horizons

The definition of a B horizon has historically differed between the *Field Handbook* and the *Australian Soil Classification*. The following amended definition of a B horizon is now adopted in both publications.[18]

Horizon in which the dominant feature is one or more of the following:

- An illuvial, residual or other concentration of silicate clay, iron, aluminium, carbonate, gypsum, manganese, or organic material, alone or in combination.
- Maximum development of pedologic organisation as evidenced by a different structure and/or consistence, and/or stronger colours than the A horizon(s) above or any horizon immediately below.

In some shallow, stony soils B horizon material may only be present in fissures within the parent rock or saprolite. In such cases there should be 50% or more (visual abundance estimate) of B horizon material for it to qualify as a B horizon

[18] This revised definition will be adopted in the next edition of the *Australian Soil and Land Survey Handbook*.

for the purposes of this classification (See also 'What do we classify' and transitional horizons).

Note: A B1 horizon is a transitional horizon between A and B, that is dominated by properties characteristic of an underlying B2 horizon.

Base status

This refers to the sum of exchangeable basic cations (Ca, Mg, K and Na) expressed in cmol(+) kg^{-1} clay. This sum is obtained by multiplying the sum of the reported basic cations (which are determined on a soil fine earth basis) by 100 and dividing by the clay percentage of the sample. Where this is not available it may be approximated from the field texture using the figures given on pp. 118–120 of the *Field Handbook*. Three classes are defined: Dystrophic – the sum is less than 5; Mesotrophic – the sum is between 5 and 15 inclusive; Eutrophic – the sum is greater than 15. An estimate of the sum of basic cations for the B horizon of an individual soil may be obtained from its classification if the B horizon maximum texture is recorded in the Family criteria.

Bauxitic horizon

Horizon that contains more than 20% (visual abundance estimate) of bauxite nodules or concretions that are mostly uncemented, and has a minimum thickness of 0.1 m.

Calcareous

Presence of carbonate segregations or fine earth (soil matrix) effervescence with 1 M HCl.

Calcareous horizon

Horizon that is usually identified as a Bk, BCk, 2Bk or 2BCk horizon, or one containing fragments of a cemented (suffix 'm') equivalent of these horizons. As noted in the *Field Handbook*, the suffix k is usually recorded only if there are more than 10% of the calcareous segregations. However in soil with no carbonate except for one horizon with few (2–10%) segregations, this could be designated with a suffix k. See also calcrete, calcrete pan and cemented pans.

Calcrete

In the *Field Handbook* calcrete is described as both a pan (i.e. a soil horizon, such as Bkm) and as a substrate material. However, the definition is the same in both cases, namely 'any cemented terrestrial carbonate accumulation that may vary significantly in morphology and degree of cementation'. The latter may be regarded as indicating the material must be hard. According to this broad definition, calcrete can obviously encompass a wide range of calcareous material although not the common soft segregations of finely divided carbonate, nor accumulations of pedogenic carbonate in the form of discrete nodules or concretions. Unfortunately, the term has been widely used in southern Australia for an almost infinite variety of forms of calcium carbonate. For the purposes of this classification, the term is used strictly as defined in the *Field Handbook*. See also calcrete pan and cemented pans.

Calcrete pan

A moderately, strongly or very strongly cemented layer of calcrete that is either continuous, or if discontinuous or broken, consists of at least 90% of hard calcrete fragments, most of which are more than 0.2 m in smallest dimension.

Carbic materials

Organic debris that has accumulated by colluvial and alluvial processes when torrential rain follows extensive bushfires. The material has a low bulk density (<1 t m^{-3}) and consists of variably carbonised plant remains, ranging from little-altered vegetative material to charcoal and humified plant debris.

Carbonate classes

The following table is a summary of the classes used in the classification for various kinds and amount of calcium carbonate.

	Soft carbonate	Hard carbonate
Hypocalcic	>0 and <2%	<20%
Calcic	2–20%	<20%
Hypercalcic	>20%	<20%
Supracalcic	≥0%	20–50%
Lithocalcic	≥0%	>50%

Cemented pans

In the *Field Handbook* a pan is defined as an indurated and/or cemented soil horizon and thus horizons such as Bcm, Bkm and Bqm could be interpreted to represent strongly developed B horizons, with consequent effects on the classification of some soils (e.g. Kandosols and Tenosols). The *Field Handbook* also recognises that it can be difficult to determine if materials such as calcrete, ferricrete and silcrete are indeed soil horizons or are better identified as substrate materials (i.e. do not show pedological development or are paleo-features).

To avoid the above problem, cemented layers such as calcrete, siliceous pan, red-brown hardpan, ferricrete, petroferric horizon and petroreticulate are recognised as diagnostic substrate features and hence excluded as criteria of B horizon development. Note that the Podosol diagnostic horizons are not regarded as substrate materials.

Clear or abrupt textural B horizon

The boundary between the horizon (normally a B2t) and the overlying horizon (that must be thicker than 30 mm and is normally an A but occasionally a B1 horizon) is clear, abrupt or sharp and is followed by a clay increase giving a strong texture contrast as per the following guidelines:

a) If the clay content of the material above the clear, abrupt or sharp boundary is less than 20% (and/or has a field texture of sandy loam or lighter), then the clay content immediately below must be at least twice as high. However, there must be a minimum of 20% clay (and/or a minimum field texture of sandy clay loam) at the top of the B horizon.
b) If the material above the transition has 20% clay or more but less than 35% clay (and/or has a field texture of loam or heavier but lighter than light clay), then the material below must show an absolute increase of at least 20% clay, for example 25% increasing clearly, sharply or abruptly to at least 45% (and/or a field texture of light medium clay or greater). Note that a clear or abrupt textural change is not allowed within the clay range (>35% clay).

	Situation a)	Situation b)
Overlying horizon	<20% clay (Sandy loam or lighter)	≥20 to <35% clay (Loam or heavier but lighter than light clay)
	Clear, abrupt or sharp boundary	Clear, abrupt or sharp boundary
B2t	Clay content twice the layer above and ≥20% clay at top of B horizon (Sandy clay loam or heavier)	Increase of at least 20% clay to a minimum of 45% clay (Light medium clay or heavier)
Typical examples	Sand (<5% clay) over light sandy clay loam or heavier (>20%) Loamy sand (~5% clay) over sandy clay loam (~25% clay)	Loam (20–25% clay) over light medium clay or heavier (>40% clay) Clay loam (30–35%) over medium to heavy clay (>50–55% clay)

Note: The field textures listed in a) and b) above must be regarded only as guidelines. Some discrepancies may arise in soils with high organic matter, silt, fine sand or soft carbonate contents, and in soils with strongly subplastic B horizons. If there are apparent discrepancies between field texture and laboratory data, the first step is to repeat the assessments if possible. If these remain unchanged the classifiers should use their own judgement based on how they think the soil behaves. In some such cases field textures may be a better guide to soil behaviour than particle size data. In all circumstances, careful sampling for analysis is required to avoid the mixing of A and B horizons, which could result in inconsistencies between field texture and laboratory data.

Note also that the above definition is similar but not directly equivalent to that of the duplex primary profile form of the Factual Key (Northcote 1979).

Colour classes

See separate entry following glossary.

Coquina

A detrital substrate consisting of cemented shells or shell fragments. The constituents are mechanically sorted (usually by sea waves), transported and often abraded because of transport and sorting. It is a porous and soft, weakly to moderately cemented material. It is not as strongly cemented as a calcrete pan, although it can be considered a form of calcrete. Geologists may describe it as detrital limestone.

Deflation

Erosion by wind of loose material from flat areas of dry, unconsolidated sediments such as those occurring in deserts, dry lake beds and floodplains.

Densipan

An earthy pan consisting of very fine sand (0.02–0.05 mm). Fragments, both wet and dry, slake in water. Densipans are less stable on exposure than underlying or overlying horizons.

Diagnostic features

The *Australian Soil Classification* uses a set of defined attributes, horizons and materials in the key to assign a soil profile to a class. Collectively these concepts are called diagnostic features. Diagnostic features were selected, as far as possible, on the basis of their likely significance to land use and soil management. Ranking of classes in the various keys is subjective and arbitrary to a varying extent (Isbell *et al*. 1997).

Some diagnostic features occur at or near the soil surface or must occur within a specified soil depth. However, others do not have a depth criterion. Although the *Australian Soil Classification* has no depth restriction, at the Great Group and Subgroup levels it is permissible to consider whether a diagnostic feature that occurs at considerable depth should apply. As a guide, if the feature begins below 1.5 m, judgement on the impact of this feature on soil performance may need to be made. The class relating to this diagnostic feature may not be the only option in the key. If it is considered that this feature has minimal influence on the performance of the soil and there are other options in the key, it is permissible to consider the next option.

Dystrophic

Base status is less than 5 cmol(+) kg^{-1} clay.

ESP (Exchangeable sodium percentage)

Since the review by Northcote and Skene (1972), an ESP of 6 has been widely used in Australia as a critical limit for the adverse effects of sodicity. ESP is conventionally defined as exchangeable sodium expressed as a percentage of the cation exchange capacity (CEC) – both usually determined in Australia at pH_w 7 or 8.5. In acid soils, particularly those with variable charge colloids, CEC at pH_w 7 or 8.5 will normally be higher than that determined at the soil pH. Hence it is more realistic to determine the effective cation exchange capacity (ECEC) (Rayment and Lyons 2010, Method 15J1), or to use an unbuffered method to determine CEC, and to use these values to calculate ESP in soils with pH_w around 5.5 or less. See also Comment after definition of Kurosols.

In some dystrophic soils, problems can arise when low levels of exchangeable sodium give rise to relatively high ESP values. In such cases there is insufficient evidence that ESP values greater than 6 have a deleterious effect on soil physical properties equivalent to that in less acid soils with higher *base status*. Further experience may indicate a need for a minimum level of exchangeable sodium to be introduced.

A related problem is the sensitivity of the analytical procedures when values for exchangeable cations and CEC and ECEC are very low. It is probably not advisable to calculate ESP when the CEC or ECEC is 3 cmol(+) kg^{-1} or less and/or exchangeable sodium is 0.3 cmol(+) kg^{-1} or less. As an indicator of sodicity, such calculations are likely to be quite misleading. This particularly applies to sandy soils with low clay content (<10%) (e.g. Arenosols) and soils that have been subject to intense weathering (e.g. many Red Kandosols).

Finally, it must be remembered that the effect of ESP on behaviour such as dispersion is also influenced by other soil properties such as organic matter content, clay mineralogy, cation composition, sesquioxide content, and particularly electrolyte concentration of the soil and of any applied irrigation water.

Eutrophic

Base status is greater than 15 cmol(+) kg^{-1} clay. If the soil horizon is not calcareous and field pH is 7 or greater, the soil will typically classify as eutrophic.

Ferric horizon

One which contains more than 20% (visual abundance estimate) of ferruginous nodules or concretions that are mostly uncemented, and has a minimum thickness of 0.1 m. Most of the nodules contain at least some manganese, and in some situations the majority (if not all) of the nodules may be transported from elsewhere.

Ferricrete

In the *Field Handbook* ferricrete is described as both a pan (i.e. a soil horizon, such as Bcm) and as a substrate material. However, the definition is the same in both cases namely 'indurated material rich in hydrated oxides of iron (usually goethite and hematite) occurring as cemented nodules and/or concretions, or as massive sheets'. This material has been commonly referred to in local usage as laterite, duricrust or ironstone. Indurated blocks or extremely coarse irregular forms (>60 mm) are defined as a petroferric horizon.

Field texture

A measure of the behaviour of a handful of soil (<2 mm fraction) when moistened and kneaded into a ball and then pressed out between thumb and forefinger.

Field textures may differ from textures derived from laboratory particle size analysis. Discrepancies may arise in soils with high organic matter, silt, fine sand or soft carbonate contents, and in soils with strongly subplastic B horizons.

If there are apparent discrepancies between field texture and laboratory data, the first step is to repeat both assessments if possible. If these remain unchanged the classifiers should use their own judgement based on how they think the soil behaves. In some cases field textures may be a better guide to soil behaviour than particle size data. In all circumstances, careful sampling for analysis is required to avoid the mixing of adjacent horizons, which could result in inconsistencies between field texture and laboratory data.

Fine earth

The less than 2 mm fraction of the soil, typically obtained by passing soil material through a 2 mm sieve.

Free iron oxide

This is 'pedogenic iron' formed by weathering of ferrous-containing primary minerals. It is determined by citrate-dithionite extract (Rayment and Lyons 2010, Method 13C1). Citrate-dithionite reacts with secondary crystalline iron oxides (e.g. hematite, goethite, lepidocrocite and maghemite) and poorly crystalline amorphous minerals but not magnetite and ilmenite.

Fusic material

A coarse fraction comprising hard, cemented (fused) ceramic-like porous fragments located within ashy material known to be derived from burnt peat. Fusic material was first observed and defined in Iraq by Fitzpatrick (2004) and more recently in a range of burnt inland acid sulfate soil profiles in the lower Murray–Darling Basin by Grealish *et al*. (2010).

Gley colours

Greyish, greenish and bluish colours found in wet soils and defined by specific Munsell Soil Color Charts – usually 10Y–5GY and Gley charts 1 & 2 (Munsell Color 2010).

Grade of pedality

Refers to the degree of development and distinctness of peds (natural structural aggregates). It is the proportion of the soil that holds together as entire peds when displaced and the ease with which the soil breaks into discrete peds. Grade is more easily determined in dry soils and may be difficult if the soils are very wet.

Grades

Apedal

- Single grain – loose, incoherent mass of individual particles. When displaced, the soil separates into ultimate particles.
- Massive – coherent. When displaced, the soil separates into fragments that may be crushed into ultimate particles.

Pedal

- Weak – peds indistinct and barely observable in undisplaced soil. When displaced, up to 1/3 of soil material consists of peds.
- Moderate – peds well formed and evident but not distinct in undisplaced soil. When displaced more than 1/3 but less than 2/3 of soil material consists of peds.
- Strong – peds quite distinct in undisplaced soil. When displaced more than 2/3 of soil material consists of peds.

More details are found in the *Field Handbook*.

Gravel

Gravel is part of the coarse fraction that is 2–60 mm in size. Gravels may be subdivided into three size classes – fine gravel (2–6 mm), medium gravel (6–20 mm) and coarse gravel (20–60 mm). Gravels include hard (when moist) coarse non-pedogenic fragments (coarse fragments in the *Field Handbook*) and segregations of pedogenic origin. The most common examples of the latter are carbonate and ferruginous nodules and/or concretions.

Gritty

Soil layer/s with a distinct sharp gritty feel due to the presence of gritty coarse sand (0.2–2 mm) and, if present, fine gravel (particle size 2–6 mm). Gritty material is composed of angular or subangular quartz or other hard rock fragments.

Gypsic horizon

One which contains more than 20% of visible gypsum that is apparently of pedogenic origin, and has a minimum thickness of 0.1 m. Where the upper boundary of the gypsic horizon first occurs below 1.0 m depth it is disregarded in the classification.

Hard

In the classification, hard is used as a general term to indicate strength. Hard nodules or segregations mean their strength is such that they cannot be broken between the thumb and forefinger (i.e. strong in the *Field Handbook*). When referring to pans, hard means moderately cemented or stronger (*Field Handbook*). When referring to substrate material, hard means moderately strong or stronger (*Field Handbook*).

Horizon

A soil horizon is a layer of soil, approximately parallel to the land surface, with morphological properties different from the layers below and above it (*Field Handbook*). The term horizon is used in two ways in this classification, first in relation to the horizon notation, for example O, P, A, B, C, D (as in the *Field Handbook*), and second in association with a specific property of a layer as defined in the glossary, for example melanic, humose, ferric, petroferric, argic.

Human activities

Activities by humans that have caused a profound modification, mixing, truncation or burial of the original soil horizons, or the creation of new soil parent materials. Examples include middens, additions of excessive organic wastes, land fill, dredge materials, and artificial soils and surface exposures created by earthmoving equipment. Normal agricultural operations, including cultivation, deep ripping, land planing, artificial drainage and flooding, are excluded. Similarly the application of liquid wastes, bore water and other irrigation waters are also excluded.

Humose horizon

This is a humus-rich surface or near surface horizon that is 0.2 m or more thick and has insufficient organic carbon to qualify as organic material. The average value for the humose horizon is more than 4% organic carbon (but <12%) if the mineral fraction contains no clay, or 6% or more organic carbon (but <18%) if the mineral fraction contains 60% or more clay; with proportional contents of organic carbon between these limits (see Fig. 2).[19] Approximate loss-on-ignition values are given under organic materials. This definition is based on that used in England and Wales (Avery 1990).

If the humose surface layer is less than 0.2 m it will not be specifically recognised as a separate texture at the Family level but will be assigned to the relevant mineral soil texture class (e.g. sandy, loamy). The one exception occurs in the Leptic Tenosols where a Subhumose Subgroup is provided.

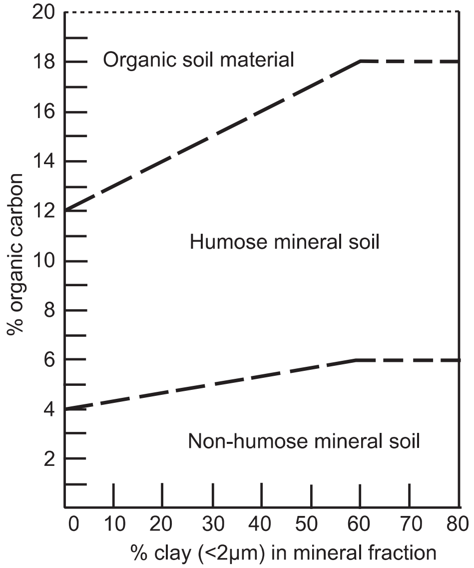


Fig. 2. Limits of organic and humose soil materials (after Avery 1990).

Hypersulfidic material

Of the three kinds of sulfidic materials, hypersulfidic material is capable of the most severe acidification as a result of sulfide oxidation. Hypersulfidic material has a field pH of 4 or more and is identified by experiencing a substantial drop in pH[20] to below 4 (1:1 by weight in water, or in a minimum of water to permit measurement) when a 2–10 mm thick layer is incubated aerobically at field capacity. The duration

[19] Walkley-Black x 1.3 or a total combustion method (Rayment and Lyons 2010, Methods 6A1 or 6B2).

of the incubation is either: a) until the soil pH changes by at least 0.5 pH unit to below 4, or b) until a stable pH[21] is reached after at least 8 weeks of incubation. This material is commonly referred to as acid sulfate soil or potential acid sulfate soil.

Hypersulfidic material should have a positive net acidity using acid-base accounting approaches (Ahern *et al*. 2004). The general formula for sulfidic materials is:

Net acidity = Potential sulfidic acidity + Existing acidity – Acid neutralising capacity

The hydrogen peroxide field test (Ahern *et al*. 2004) may be used as a field indicator of hypersulfidic material (confidence level 3) but confirmation of this classification requires incubation testing (confidence level 1).

Hyposulfidic material

Of the three kinds of sulfidic materials, hyposulfidic material is intermediate to weak in its degree of acidification as a result of sulfide oxidation. Hyposulfidic material: (i) has a field pH of 4 or more, and (ii) does not experience a substantial drop in pH[20] to below 4 (1:1 by weight in water, or in a minimum of water to permit measurement) when a 2–10 mm thick layer is incubated aerobically at field capacity. The duration of the incubation is until a stable pH[21] is reached after at least 8 weeks of incubation.

Hyposulfidic material should have a zero or negative net acidity using acid-base accounting approaches (Sullivan *et al*. 2018b). The general formula for sulfidic materials is:

Net acidity = Potential sulfidic acidity + Existing acidity – Acid neutralising capacity.

The field pH peroxide test (Ahern *et al*. 2004) may be used as a field indicator of hyposulfidic material (confidence level 3) but confirmation of this classification requires incubation testing (confidence level 1). In combination with a positive test of the fine earth as calcareous (the effervescence test, Ahern *et al*. 2004), assignation of a confidence level of 2 is reasonable.

Lamellae

Thin, often discontinuous, layers of clay-enriched material.

Layer

A general term for a distinct band of soil or other material approximately parallel to the land surface. By comparison, the term horizon refers to a layer where a

20 A substantial drop in pH arising from incubation is regarded as an overall decrease of at least 0.5 pH unit.

21 A stable pH is assumed to have been reached after at least 8 weeks of incubation when either the decrease in pH is <0.1 pH unit over at least a 14 day period, or the pH begins to increase.

notation (e.g. O, P, A, B, C, D) or a specific property (e.g. melanic, humose, ferric, petroferric, argic) is assigned to the layer. See definition of Horizon.

Loss-on-ignition (LOI)

An analytical test involving strongly heating ('igniting') a sample of the material at a specified temperature, allowing volatile substances to escape, until its mass ceases to change. This simple test is used to estimate total organic carbon and carbonate. See method 6G1 in Rayment and Lyons (2011).

Major part

The requirement must be met over more than half the specified thickness.

Manganic horizon

One which contains more than 20% (visual abundance estimate) of black manganiferous nodules or concretions that are mostly uncemented, and has a minimum thickness of 0.1 m. Most nodules also contain some iron.

Marl

A loose, earthy material consisting chiefly of an intimate mixture of clay and calcium carbonate, commonly formed in freshwater lakes. The carbonate content may range from ~30–90% (Bates and Jackson 1987).

Mean Low Water Springs (MLWS)

The average of all low water observations at the time of the spring tides over a period of time, preferably 19 years. It is applicable in semi-diurnal waters only (Permanent Committee on Tides and Mean Sea Level 2014).

Melacic horizon

As for melanic horizon but pH_w is less than 5.5 and there is no structure requirement.

Melanic horizon

This is a dark surface or near surface horizon that has insufficient organic carbon to qualify as a humose horizon, and has little if any evidence of stratification. It has all of the following properties:

1. Moist colour is black throughout (i.e. value 3 or less and chroma 2 or less – see Colour classes) and dry colour value is 5 or less.
2. A minimum thickness of 0.2 m (in soils with a clear or abrupt textural B horizon the minimum thickness must be present within the A horizon).

3. The major part of the horizon has more than a weak grade of structure in which the most common ped size is 10–20 mm or less. This condition may be waived for an *Ap horizon* or when dry consistence strength is weak or less.
4. pH_w is 5.5 or greater throughout the major part of the horizon.

Mesotrophic

Base status is between 5 and 15 cmol(+) kg^{-1} clay inclusive.

Monosulfidic black ooze (MBO)

A form of *monosulfidic material* comprising amorphous gels that contain high concentrations of iron monosulfide minerals (general formula FeS). These minerals form in the base of low-flow surface water bodies in acid sulfate soil–influenced environments. MBOs are highly reactive in the presence of oxygen, breaking down in a matter of minutes to produce free iron and acidity. The reactions are controlled by the presence of oxygen in the water, and their disturbance can cause significant deoxygenation events in natural waters, killing aquatic life. MBOs may sometimes be referred to as iron monosulfides, monosulfides or acid volatile sulfides (Sullivan *et al*. 2018a).

Monosulfidic material

Of the three kinds of *sulfidic materials*, *monosulfidic material* is the only one that contains high concentrations of detectable monosulfides (≥0.01% acid volatile sulfide). *Monosulfidic material* is conceptually similar to *monosulfidic black ooze* (MBO, Sullivan *et al*. 2018a); however, it differs from MBO in that monosulfidic material encompasses a wider array of soil textures and consistencies. For example, monosulfidic material includes sands with ≥0.01% acid volatile sulfide, which are excluded (on the basis of soil consistence) from being MBOs.

Field identification features for *monosulfidic material* include: (i) complete saturation; (ii) an ooze-like consistency and low bulk density (for non-sands); (iii) a change in colour on exposure from black (dark) to greyish (lighter) colours; (iv) the lead acetate test paper for hydrogen sulfide; and (v) a 'rotten egg' smell of hydrogen sulfide using the so-called 'whiff test' of Darmody *et al*. (1977). (**Caution**: hydrogen sulfide is a toxic gas and care should be taken with this test – a broad sweep of the hand to the nose in the open air while approaching a small sample of the material is commonly used.)

Mottled horizon

A horizon in which mottle abundance is greater than 10% (visual abundance estimate) and contrast between colours is distinct to prominent. Colour patterns due to biological or mechanical mixing, and inclusions of weathered substrate materials, are not included. As pointed out (see Comment – Hydrosols), mottling does not necessarily imply that oxidising and reducing conditions are currently occurring in the soil in most years.

Organic materials

These are plant-derived organic accumulations that are either:

a) saturated with water for long periods or are artificially drained and, excluding live plant tissue, (i) have 18% or more organic carbon [Walkley-Black × 1.3 or a total combustion method (Rayment and Lyons 2011, Methods 6A1 or 6B2)] if the mineral fraction is 60% or more clay, (ii) have 12% or more organic carbon if the mineral fraction has no clay, or (iii) have a proportional content of organic carbon between 12 and 18% if the clay content of the mineral fraction is between zero and 60% (see Fig. 2), or
b) saturated with water for no more than a few days and have 20% or more organic carbon.

This definition is the same as that used in *Soil Taxonomy* (Soil Survey Staff 2014) and is very similar to that used in England and Wales (Avery 1990).

Loss-on-ignition (LOI) may also be used as an estimate of organic carbon. For non-calcareous soils, the relationship between organic carbon and LOI was found by Spain *et al.* (1982) to be influenced by clay content. This is due to losses of structural water from clay minerals affecting the result. For the range of organic carbon contents of interest, approximate conversions are:

	Clay (%)	LOI
when clay is	<20%	2.0 × organic carbon
	20–60%	2.3 × organic carbon
	>60%	2.7 × organic carbon

Peat

As noted in the *Field Handbook*, peats may be assessed by examining the degree of decomposition and distinctness of plant remains. This may be assisted by using a modification of the von Post field test (see Avery 1990, p. 90), in which a sample of the wet peat is squeezed in the closed hand and the colour of the liquid expressed, the proportion extruded between the fingers, and the nature of the plant residues are observed. Refer to the *Field Handbook* for further information.

Fibric Peat. Undecomposed or weakly decomposed organic material; plant remains are distinct and identifiable; yields clear to weakly turbid water; no peat escapes between fingers.

Hemic Peat. Moderately to well decomposed organic material; plant remains recognisable but may be rather indistinct and difficult to identify; yields strongly turbid to muddy water; amount of peat escaping between fingers ranges from none up to 1/3; residue is pasty.

Sapric Peat. Strongly to completely decomposed organic material; plant remains indistinct to unrecognisable; amounts ranging from about half to all escape between fingers; any residue is almost entirely resistant remains such as root fibres and wood.

Peaty horizon (P and O2 horizons in the *Field Handbook*)

This is a surface or near surface layer of organic materials at least 0.2 m thick overlying mineral soil and which does not qualify as an Organosol. Such soils are designated as a peaty Subgroup. In cases where the soil has a surface layer of organic materials less than 0.2 m thick but does not qualify for an Organosol (e.g. as in Definition 2 of Organosols), it will be recognised at the Family level as having a peaty 'texture'. There are two exceptions (in Leptic Tenosols and Arenosols) where a Subpeaty Subgroup is provided. In the Peaty and Subpeaty Subgroups there will be a repetition of texture at the Family level.

Pedologic organisation

This is a broad term used to describe evidence of soil formation, which includes all changes in soil material resulting from the effect of physical, chemical and biological processes. Results of these processes include horizonation, colour differences, presence of pedality and texture and/or consistence changes.

Petroferric horizon

Ferruginous, ferromanganiferous or aluminous nodules or concretions cemented in place into indurated blocks or extremely coarse irregular pieces (>60 mm). This horizon is commonly referred to as ferricrete.

Petroreticulate horizon

A reticulate horizon (see below) that is always indurated in the greater part both before and after exposure.

pH

Unless otherwise specified, pH refers to pH_w (1:5 soil:H_2O, Rayment and Lyons 2011, Method 4A1). Field pH methods that approximate this value are by measuring a hand shaken 1:5 soil:H_2O solution by pH probe or by using the Inoculo CSIRO Soil pH Testing Kit. Approximate equivalents for pH_w and pH_{Ca} (1:5 soil: 0.01M CaCl2) for the critical pH values used in the classification are as follows (based on regressions given by Ahern *et al.* (1995) for large numbers of Queensland surface and subsoil samples):

- pH_w of 5.5 is approximately equivalent to pH_{Ca} of 4.6
- pH_w of 4.0 is approximately equivalent to pH_{Ca} of 3.5

Podosol diagnostic horizons

The various B horizons defined below consist of illuvial accumulations of amorphous organic matter-aluminium and aluminium-silica complexes, with or without iron in various combinations. Although some may qualify as cemented pans, they are not to be regarded as substrate materials.

Bs horizons

The usually bright colours indicate that iron compounds are strongly dominant or co-dominant and there is little evidence of organic compounds, apart from a few usually discontinuous patches in the upper B horizon or a thin band (<50 mm thick) at the A2/B junction. The upper boundary of the B horizon may be very uneven but otherwise the horizons are relatively uniform laterally. Iron concentrations may increase or decrease with depth. No strongly coherent Bs horizons have been recorded. Bs horizons may be non-reactive or give only a weak response to the reactive aluminium test. As a guide, Bs horizons usually have a hue of 5, 7.5 or 10YR, a value of 4 or 5, and a chroma of 4–8.

Note that the presence of a thin ironpan (placic horizon), which will be designated as Bsm, is not to be regarded as a Podosol diagnostic horizon because it may also occur in the B horizon of other soils, for example Tenosols and Kandosols, and may also be present in C horizons or even parent rocks.

Bhs horizons

Iron and organic compounds are both prominent with the organic compounds distributed as streaks, patches or lumps so that concentrations of iron, aluminium and organic compounds have marked spatial variation. Such horizons may contain firm lumps of organic compounds but otherwise are weakly coherent and highly permeable, or they may be strongly coherent throughout, or contain strongly coherent subhorizons or pans. Bhs horizons always contain significant amounts of oxalate-extractable iron and aluminium and frequently silica, that is, an imogolite-allophane complex is usually present in significant amounts and the horizons give a moderate to very strong response to the reactive aluminium test. As a guide, Bhs horizons usually have a hue of 2.5YR to 10YR, and value/chroma of 3/3, 3/4, 3/6, 4/3 or 4/4.

Bh horizons

Organic-aluminium compounds are strongly dominant with little or no evidence of iron compounds. Such horizons have a uniform appearance laterally and are relatively uniform vertically although concentrations of carbon and aluminium and the degree of coherence or cementation may change with depth. The horizons may be weakly or strongly coherent, or contain strongly coherent or cemented subhorizons or pans, or overlie other kinds of pans or clay D horizons. Bh horizons are non-reactive or give only a weak response to the reactive aluminium test. Colours are usually dark with values <4 and chromas <3. In typical Bh horizons the sand grains are uncoated and the organic-aluminium complex is precipitated between the grains (Farmer *et al*. 1983).

Bh/Bhs horizons

These have a subhorizon, dominated by organic and aluminium compounds with relatively low iron (Bh), overlying the major horizon with prominent organic and iron compounds (Bhs). The dark horizon (Bh) may undulate but is usually discontinuous, and rests on or grades into a Bhs with a range in consistence as described above.

Bh/Bs horizons

The dark Bh horizon may be weakly or strongly coherent, but is usually discontinuous and grades quickly to a brightly coloured and weakly coherent Bs horizon.

Basi horizons

These are brown, yellow-brown or pale brown cemented horizons that immediately underlie Bh horizons in some poorly drained Podosols. Despite their colour these horizons have low contents of acid oxalate-extractable iron but significant amounts of oxalate-extractable aluminium and silica. The cementing agency appears to be an imogolite-allophane complex with some organic-aluminium compounds. These horizons give a rapid strong or very strong response to the reactive aluminium test. Because of their bright colour and cementation many of these horizons have been included as ortstein in the past.

Bh/Basi horizons

Typical Bh horizons dominated by organic-aluminium compounds that may be weakly coherent or cemented and overlie a cemented Basi horizon.

Pipey B horizons

These horizons are characterised by pipes of bleached A2 horizon that penetrate both vertically and sometimes laterally >0.5 m into the B horizon, giving a tongued boundary on a profile face. The pipes are usually enclosed by dark organic compounds forming the pipe walls of Bh or Bh/Bhs materials that usually have a weak to firm consistence strength (i.e. force 2–3) and are brittle when dry. The bleached A2 material consists of clean quartz grains that have lost any oxide coatings. In ‘giant’ Podosols the pipes may penetrate >6 m into the B horizon.

Reactive aluminium test (Hewitt 1992)

This test indicates the presence of reactive hydroxy-aluminium groups, as occur for example in allophane and aluminium-humus complexes (Milne *et al*. 1991).

Using the procedure of Fieldes and Perrott (1966), 1 drop of saturated sodium fluoride solution is carefully placed on a small test sample of soil, which has been smeared on to a filter paper treated with phenolphthalein indicator. The soil sample must be field moist. For classification, the reactivity of the soil sample is placed into one of the following classes.

(**Caution:** sodium fluoride is a toxic liquid, and care should be taken with this test.)

Reactivity Class	Class Definition
0 non-reactive	No colour within 2 minutes.
1 very weak	Pale red or light red (5R 6/1) just discernible within 2 minutes.
2 weak	Pale red or light red (5R 6/1) within 1 minute.
3 moderate	Red or weak red (5R 4 or 5/-) within 1 minute.
4 strong	Dusky red or dark red (5R 3/-) after 10 seconds.
5 very strong	Dusky red or dark red (5R 3/-) within 10 seconds.

Red-brown hardpan

An earthy pan that is normally reddish brown to red with a dense yet porous appearance. It is very hard, has an irregular laminar cleavage and some vertical cracks, and varies from less than 0.3 m to over 30 m thick. Wavy black veinings, probably manganiferous, are a consistent feature while other more variable features include bedded and unsorted sand and gravel lenses and, less commonly, off-white veins of calcium carbonate. The red-brown hardpan appears to occur either as a cemented sediment or a cemented palaeosol (Wright 1983). It is one of a variable group of silica pans generally known as duripans (Soil Survey Staff 1999) that commonly occur in currently arid climates.

Reticulate horizon

A strongly developed reddish, yellowish and greyish or white, more or less reticulately mottled horizon that can be hand-augered or cut with a spade. Ferruginous nodules or concretions may be present but are not diagnostic. When moist, the material usually has at least a firm consistence strength, but following exposure the material may irreversibly harden. At depth it may grade into mottled saprolite.

Silcrete

In the *Field Handbook* silcrete is described as both a pan (i.e. a soil horizon, such as Bqm) and as a substrate material. However, the definition is the same in both cases, viz strongly indurated siliceous material cemented by, and largely composed of, forms of silica, including quartz, chalcedony, opal and chert.

Siliceous pan

A moderately, strongly or very strongly cemented layer enriched with silica and commonly described as silcrete. The pan is either continuous, or if discontinuous or broken, consists of at least 90% of hard fragments, most of which are more than 0.2 m in smallest dimension.

Slickensides and/or lenticular peds

Slickensides are shrink-swell shear features (e.g. grooves, striations, glossy surfaces) on ped faces. Lenticular peds are overlapping, lens-shaped peds that are thick at the centre and taper towards the edges.

Sodic

The ESP of the fine earth soil material is 6 or greater.

Soil

A natural body consisting of layers or horizons of mineral and/or organic constituents of variable thickness which differ from their parent material in their morphological, physical, chemical and mineralogical properties and their biological characteristics (Birkeland 1984). Note that Anthroposols are not strictly natural bodies and the properties of some Rudosols and Arenosols may not differ much from their parent materials.

Soil depth

One of the most important features of a soil is its depth or thickness, but it is frequently difficult to determine the lower limit of soil. For many purposes depth of soil is considered to be synonymous with the rooting depth of plants, however as plant species vary widely in their rooting depth it is not always a suitable criterion. Thickness of solum (P + A + B horizons) is a measure that is useful in many soils, although it may be difficult in some soils to distinguish B from C or D horizons.

In soils underlain by unconsolidated mineral materials, the unconsolidated materials can be included in soil depth calculations.

At the Family level, soil depth will be taken to mean either thickness of the soil profile or depth to cemented pans, other cemented materials, rock or saprock. It is measured from the soil surface, including any O2, P1 or P2 horizons, if present. In a particular soil it will be evident from the classification which criterion is used. However, depth to a thin ironpan will not be used because of the extremely irregular and convoluted nature of most such pans.

Soil profile

A general term for a vertical section of soil from the surface through all its horizons to parent material, other consolidated substrate material or selected depth in unconsolidated mineral material. Commonly abbreviated to the term soil. Compare with Solum. See also Soil depth.

Solum

The surface and subsoil layers that have undergone the same soil forming conditions. In terms of soil horizon designations, a solum consists of A and B horizons and their transitional horizons and P and O2 horizons. A solum does not have a maximum or a minimum thickness. Compare with Soil profile. Plural sola.

Strongly acid

pH of the fine earth soil material is as follows:

- pH_w is less than 5.5 or
- pH_{Ca} is less than 4.6.

pH_w <5.5 should be used as the critical limit when it is available.

Strongly coherent B horizon

These are Podosol *B horizons* in which the consistence strength ranges from very firm to strong throughout (i.e. force 4–5), or they contain subhorizons with these properties. Included are pan-like materials that have been variously described as ortstein, coffee rock or sandrock. The consistence properties are usually independent of soil water status.

Strongly developed

This is a broad term used to describe strong evidence of pedologic organisation. It includes obvious horizonation such as strongly contrasting colour differences, the presence of pedality and accumulations, and texture and/or consistence changes between horizons.

Strongly subplastic

Field texture increases more than 2 texture groups after 10 minutes kneading. Compare with subplastic.

Subaqueous soil

This is submerged soil material that may occur in both inland and tidal settings. With Australia's seasonal climate some inland forms may experience rare periods of exposure during extreme drought. For soil materials exposed more frequently than one year in nine, on average however, the definition does not apply; more frequent drought-induced exposed lake beds and wetlands do not classify as Subaqueous.

Sediments in shallow water environments undergo soil forming processes (Demas and Rabenhorst 1999, 2001), are capable of supporting rooted plants, and meet the definition of pedologic organisation used in the *Australian Soil Classification* to distinguish soil material.

The depth range of the water column where these soils may be found is not known, and an arbitrary depth of 2.5 m below the surface or MLWS is used. This aligns closely with the definitions of subaqueous and submerged soils adopted by the USDA.

Subplastic

Field texture increases 1 to 2 texture groups after 10 minutes kneading. Compare with strongly subplastic.

Subtidal soil

This is permanently saturated subaqueous soil material bordering intertidal flats or other coastal features adjacent to MLWS (e.g. beaches, dunes, headlands).

Sulfidic materials

These are soil materials containing detectable inorganic sulfides (≥0.01% sulfidic sulfur) that can exist as horizons or layers at least 30 mm thick or as surface features. The laboratory measurements of sulfidic sulfur include elemental sulfur as well as various iron sulfide minerals such as pyrite, greigite, mackinawite, marcasite, iron (II) sulfide and pyrrhotite. Ahern *et al*. (2004) describe a range of methods used in Australia and their applicability. The preferred laboratory method for dry soil samples is the chromium reducible method (SCR) (Sullivan *et al*. 2010). Where monosulfidic material is suspected, the samples should be analysed using the chromium reducible method in field condition with minimal disturbance arising from storage, desiccation, etc.

Sulfidic materials accommodate: (i) a diverse range of seasonally or permanently waterlogged soil materials, and (ii) materials that are almost entirely formed under anaerobic conditions (i.e. experience a reducing environment for all or part of the period of saturation).

It is usually possible to assess in the field, the likelihood of soil layers or horizons possessing certain types of sulfidic materials by using surrogate criteria with 'Confidence Levels of Classification'.

Extensive revisions of the Australian classification of sulfidic materials have been proposed by Sullivan *et al*. (2010) and there is considerable diversity of opinion on the desirability, nature and efficacy of detailed chemical criteria to define sulfidic materials. For this reason *Soil Taxonomy* (Soil Survey Staff 2014) and the *World Reference Base* (2015) have deliberately avoided the use of chemical (e.g. Acid Base Accounting) and mineralogical criteria. However, this broad definition of sulfidic materials is deliberately general in nature.

Three kinds of sulfidic materials are distinguished, based essentially on the specific nature and amounts of the various oxidisable sulfur minerals present and the neutralizing capacity of the material. The three kinds defined elsewhere in the glossary are: (i) hypersulfidic material, (ii) hyposulfidic material and (iii) monosulfidic material.

Sulfuric material[22]

Soil material that has a pH less than 4 (1:1 by weight in water, or in a minimum of water to permit measurement) when measured in dry season conditions as a result of the oxidation of sulfidic materials (defined above). This material has commonly been called actual acid sulfate soil. Evidence that low pH is caused by oxidation of sulfides is one of the following:

- yellow mottles and coatings of jarosite (hue of 2.5Y or yellower and chroma of ~6 or more), or
- underlying hypersulfidic material.

Tephric materials

These consist dominantly of tephra – unconsolidated, non-weathered or only slightly altered primary pyroclastic products of explosive volcanic eruptions. They include ash, cinders, lapilli, scoria, pumice and pumice-like vesicular pyroclastics. Volcanic bombs may occur, and some exotic ejecta such as limestone fragments.

Thin ironpan

Commonly a thin (2–10 mm) black to dark reddish pan cemented by iron, iron and manganese, or iron-organic matter complexes. Rarely 40 mm thick. It has a wavy or convolute form and usually occurs as a single pan. It is also known as a placic horizon (Soil Survey Staff 2014).

[22] This definition is similar to that in Soil Taxonomy (Soil Survey Staff 2014) but modified slightly by Dr David Dent, Sullivan *et al.* (2010) and colleagues in CSIRO.

Transitional horizons

There are slight differences in the definitions of these horizons between the *Field Handbook* and the Soil Survey Manual (Soil Science Division Staff 2017), and the definitions used in this classification are those used in the Soil Survey Manual, viz:

- Horizons dominated by properties of one master horizon but having subordinate properties of another (e.g. BC). The first letter designates the horizon whose properties dominate the transitional horizon.
- Horizons that have in combination two distinct parts that have recognisable properties of the two kinds of master horizons, indicated by two capital letter symbols (e.g. C/B). The first letter indicates the horizon with the greater volume. Most of the individual parts of one horizon component are surrounded by the other. The designation may be used even when horizons similar to one or both of the components are not present, provided that the separate components can be recognised in the combination horizon.

Unconsolidated mineral materials

This term is used to describe various unconsolidated materials below the solum, such as some C horizons, buried soils, sedimentary deposits of alluvial, colluvial or aeolian origin, and transported gravels or ferruginous nodules or concretions, such as occur in some ferric and bauxitic horizons. Many of these sediments may be defined as D horizons.

Vertic properties

Soil material with a clayey field texture (i.e. light clay, medium clay, heavy clay) or 35% or more clay, that cracks strongly when dry and has slickensides and/or lenticular peds. See also Comment following the definition of Vertosols.

In several countries, physical measurements are being used in soil classification to help define classes of shrink-swell clay soils. In South Africa (Soil Classification Working Group 1991), the definition of a vertic A horizon (which is the definitive feature of soils equivalent to Vertosols) includes either slickensides or a plasticity index greater than 32 (using the SA Standard Casagrande cup to determine liquid limit) or greater than 36 (using the British Standard cone to determine liquid limit). Cracking is regarded as an accessory property, as is linear shrinkage which is stated to be usually greater than 12%. In the *World Reference Base* (2015), part of the Vertosol definition is the requirement for a vertic horizon that has a COLE (coefficient of linear extensibility) of 0.06 or more averaged over the depth of the horizon.

Soil Taxonomy (Soil Survey Staff 2014) relies solely on morphology for the definition of Vertisols (as does *World Reference Base* 2015), but in the definition of vertic Subgroups in *Soil Taxonomy* a linear extensibility of 60 mm or more is offered as an alternative to the usual morphological requirements of cracks, and slickensides or wedge-shaped aggregates.[23] However, the 60 mm minimum applies to the soil in the upper 1.0 m of the profile, or the depth to a lithic or paralithic contract, whichever is shallower. This hardly seems appropriate to a common Australian situation where thick sandy A horizons overlie shrink-swell B horizons, particularly as in most engineering situations topsoils tend to be removed.

In Australia, COLE is seldom determined other than for research purposes and hence there is no appropriate database of representative Australian clay soils. In contrast, standard engineering tests (Atterberg limits and linear shrinkage) are widely used by engineers and some soil conservation departments. Unfortunately, it is often not possible to relate the test values to specific kinds of soil, let alone the presence or absence of morphological features such as slickensides and lenticular peds. One relevant paper is that of Mills *et al*. (1980) who found in a study of 14 clay subsoils (three of which were Vertosols) in New South Wales that linear shrinkage was an appropriate method to predict shrink-swell activity but this was not related to morphology. Critical linear shrinkage limits of Mills *et al*. (1980) and for several other engineering authorities are given by Hicks (1991). Linear shrinkage values of 12–17% are rated as being marginal or moderate, with greater than 17% rated as a critical or high shrink-swell potential. However, Holland and Richards (1982) suggest that in arid and semi-arid climates, where pronounced short, wet and long, dry periods lead to major moisture changes, the linear shrinkage lower limits for moderate and high shrink-swell potential be 5% and 12% respectively.

McKenzie *et al*. (1994) have suggested that because the natural soil fabric is destroyed in the standard linear shrinkage test, the results can be difficult to relate to field behaviour. They have developed a rapid modified linear shrinkage test in which disruption to the natural soil fabric is reduced. This method was found to be a good predictor of COLE ($r^2 = 0.88$) with the slope of the regression line close to unity. The standard linear shrinkage was found to be a weaker predictor of COLE ($r^2 = 0.79$). In the 26 samples used (that included two Vertosol profiles), the value for the standard linear shrinkage was always equal to or greater than the modified method.

There is obviously a need for further testing of all shrinkage methods on a wide range of Australian soils, and in particular to relate values to field morphology, as the latter may not always be a reliable guide to shrink-swell behaviour, particularly if salt and carbonate contents are high. McGarry (2002) has reviewed the various methods currently used to measure soil shrinkage.

For present classification purposes it is difficult to give firm guidelines. In the interim, a linear shrinkage of ~8% or greater by the modified version or ~12% or greater by the standard linear shrinkage (and/or a plasticity index >32–36) will help differentiate soils with vertic properties from others.

[23] The linear extensibility (LE) of a soil layer is the product of the thickness, in centimetres, multiplied by the COLE of the layer in question. The LE of a soil is the sum of these products for all soil horizons (Soil Survey Staff 2014).

Vesicular pores

Soil pores characterised by the presence of vesicles or bubble-like structures, often associated with surface horizons and high salt concentrations in dry environments.

Water repellence

Water repellence is a property of some soils, commonly with sandy textures, that resist wetting by water. It is caused by a series of long chain polymethylene waxes, made up of acids, alcohols and esters, attached to sand grains. Degree of water repellence is assessed by determining the concentration of ethanol required to wet the soil in 10 seconds (King 1981). An abbreviated form of this method in the *Field Handbook* is recommended for routine field situations and is included as a Family criterion in susceptible Orders.

Water repellence generally occurs in the surface layers of sandy soils and is typically associated with medium to coarse sands containing <5% clay. Fine to medium sands with 5–10% clay are less prone to water repellence.

Weakly coherent B horizon

These are Podosol *B horizons* in which the consistence strength ranges from loose to firm (i.e. force 0–3), although they may contain firm to very firm lumps (i.e. force 3–4) associated with accumulations of organic compounds, and occasionally there may be some hard sesquioxide nodules present. They do not contain pans of any kind.

Weakly developed

This is a broad term used to describe weak evidence of pedologic organisation. It includes poorly expressed horizonation such as minimal colour differences, weak pedality, few accumulations and little, if any, texture and/or consistence changes between horizons.

Wet panning

A process where material is added to a pan and gently agitated in water. Materials with a low specific gravity are allowed to spill out of the pan, whereas materials with a higher specific gravity sink to the bottom of the sediment during agitation and remain within the pan for examination. For a detailed description of the method, readers are referred to British Geological Survey (2001).

Colour Classes

The class limits shown below (Fig. 3) have been chosen after examination of the Munsell Soil Color Charts (Munsell Color 2010) and the scheme used for grouping in the Factual Key (Northcote 1979). A major aim was to achieve class limits as simple as possible and to standardise on these throughout the system. The proposed scheme has the virtue of simplicity although some may argue that 2.5YR 4/2 for example is not very grey, nor is 5YR 8/3 very red. These discrepancies can of course be removed, but at the cost of simplicity. Some of the more obvious 'misfits' are probably rare in soils. Colours should be matched to the chip closest in colour, or the nearest whole number in chroma where chips are not provided, for example chromas 5 and 7.

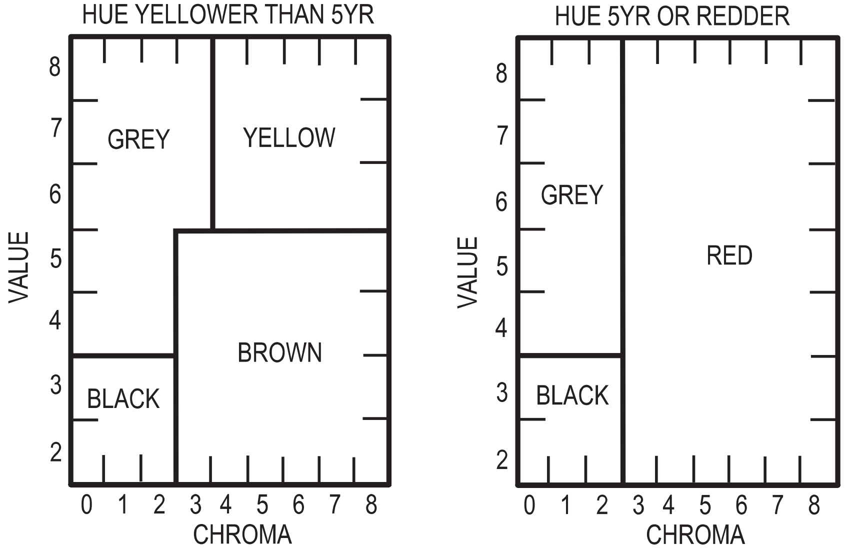


Fig. 3. Colour class limits. DO NOT use this in lieu of Munsell Soil Color Charts (Munsell Color 2010) in the field.

Black	The dominant colour (moist) for all hues has a value of 3 or less and a chroma of 2 or less.
Red	The dominant colour (moist) has a hue of 5YR or redder and a chroma of 3 or more.
Brown	The dominant colour (moist) has a hue yellower than 5YR and a value of 5 or less and a chroma of 3 or more.
Yellow	The dominant colour (moist) has a hue yellower than 5YR and a value of 6 or more and a chroma of 4 or more.
Grey	The dominant colour (moist) for all hues has a value of 4 or more and chroma 2 or less; for hues yellower than 5YR values of 6 or more and chromas of 3 are allowed.

Gley colours

Greyish, greenish and bluish colours found in wet soils and defined by specific Munsell Soil Color Charts – usually 10Y–5GY and Gley charts 1 & 2 (Munsell Color 2010).

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Appendix 1: Use of codes and confidence levels in recording classification of soil profiles

Use of codes

Examples of a coded classification of a soil profile are presented below. The codes are listed in the following order: Confidence level, Order, Suborder, Great Group, Subgroup, Family criteria. Note that the general written form of the classification is largely in reverse order with the following syntax: Subgroup, Great Group, Suborder Order; Family criteria, (Confidence level).

This ordering is not prescriptive and the manner in which the classification is recorded on field data sheets is an operational matter. However, the national standard soil profile database design, developed by the Australian Collaborative Land Evaluation Program (ACLEP), specifies that the coding system outlined in this classification is to be used for data exchange.

Example 1

1 CH AA AH AT A F L O T WR

This would decode as Bleached, Eutrophic, Red Chromosol; thin, slightly gravelly, loamy, clayey, very shallow, water repellent, (Confidence level 1).

Example 2

If a level within the classification hierarchy is indeterminable from the available information this may be coded as [YY] but only if classes at the lower level are applicable:

4 KA AA YY BU

Ferric, ?, Red Kandosol; (Confidence level 4), where YY is defined as: ***Class undetermined***.

Example 3

If there is no available class this should be coded as [ZZ]:

1 RU ER ZZ AR

Basic, n/a, Stratic Rudosol; (Confidence level 1), where ZZ is defined as: ***No available class***.

Example 4

If only a subset of the Family criteria has been recorded then this should be coded as follows:

1 TE IN EA AI A - K K –

Acidic, Petroferric, Red Tenosol; thin, -, sandy / sandy, -, (Confidence level 1), where - is defined as: ***Not recorded***

In this example it is important to note that Family criteria with a code of 'K' is valid for '*A1 horizon* texture' and 'B horizon maximum texture'. Recording of all the Family criteria is essential. In order to avoid any future confusion or ambiguity, it is essential to record the Family criteria in the same order as they are presented in the publication.

Confidence level of classification

In several instances it will not be possible to fully classify the soil because of a lack of laboratory data or limited inspection of the full profile depth. It is desirable to indicate the level of confidence (1–4) when any attempt at classification is made.

1. All necessary analytical and/or morphological data are available for the profile being classified.
2. Necessary analytical and/or morphological data for the profile are incomplete but are sufficient to classify the soil with a reasonable degree of confidence, for example free iron oxide data may be lacking but it is known that the soil is formed from basalt. Such a soil invariably has >5% free iron oxide and would be considered a Ferrosol. Soils with all necessary analytical and/or morphological data but only to a limited profile depth may also fit this confidence level.
3. No necessary analytical or limited morphological data are available for the profile but confidence is fair, based on a knowledge of similar soils in similar environments, for example presence of columnar structure is normally a reliable indicator of sodic soils (Sodosols).
4. No necessary analytical or only limited morphological data are available for the profile and the classifier has little knowledge or experience with this kind of soil, hence the classification is provisional.

Appendix 2: List of codes and equivalent class names

Table A1. Order, Suborder, Great Group and Subgroup

* introduced in the revised edition

\+ introduced in second edition

\# introduced in third edition

^ no longer used

@ discontinued after first edition but reintroduced with revised definition in third edition

CODE	NAME
AA	Red
AB	Brown
AC	Yellow
AD	Grey
AE	Black
AF	Dystrophic
AG	Mesotrophic
AH	Eutrophic
AI	Acidic
AJ	Acidic-Mottled
AK	Andic
AL	Aeric
AM	Aquic
AN	Anthroposols
AO	Arenic
AP	Argic
AQ	Argillaceous
AR	Basic
AS	Bauxitic
AT	Bleached
AU	Bleached-Acidic
AV	Bleached-Ferric
AW	Bleached-Leptic

CODE	NAME
AX	Bleached-Magnesic
AY	Bleached-Manganic
AZ	Bleached-Mottled
BA	Bleached-Sodic
BB	Bleached-Vertic
BC	Calcareous
BD	Calcic
BE	Chernic
BF	Chernic-Leptic
BG	Chromosolic
BH	Crusty
BI	Densic
BJ	Duric
BK	Pedaric
BL	Endoacidic
BN	Episodic
BP	Endohypersodic
BR	Epihypersodic
BT	Extratidal
BU	Ferric
BV	Arenaceous
BW	Fibric
BX	Fluvic

CODE	NAME
BY	Fragic
BZ	Gypsic
CA	Calcarosol
CB	Calcarosolic
CC	Halic
CD	Haplic
CE	Hemic
CF	Histic
CG	Humic
CH	Chromosol
CI	Humic/Humosesquic
CJ	Humic/Sesquic
CK	Humose
CL	Humose-Magnesic
CM	Humose-Mottled
CN	Humose-Parapanic
CO	Humosesquic
CP	Hypervescent
CQ	Hypercalcic
CR	Hypernatric
CS	Hypersalic
CU	Epihypersodic-Epiacidic
CV	Hypocalcic
CW	Intertidal
CX	Kurosolic
CY	Leptic
CZ	Lithic
DA	Lithocalcic
DB	Magnesic
DC	Manganic
DD	Marly
DE	Dermosols
DF	Massive
DG	Melacic
DH	Melacic-Magnesic
DI	Melacic-Mottled
DJ	Melacic-Parapanic

CODE	NAME
DK	Melanic
DL	Melanic-Bleached
DM	Melanic-Mottled
DN	Melanic-Vertic
DO	Mellic
DP	Mesonatric
DQ	Mottled
DR	Subhumose
DS	Orthic^
DT	Oxyaquic
DU	Paralithic
DV	Parapanic
DW	Peaty
DX	Peaty-Parapanic
DY	Pedal
DZ	Petrocalcic
EA	Petroferric
EB	Pipey
EC	Placic
ED	Redoxic
EE	Rendic
EF	Reticulate
EG	Salic
EH	Sapric
EI	Self-mulching
EJ	Semiaquic
EK	Sesquic
EL	Shelly
EM	Silpanic
EN	Snuffy
EO	Sodic
EP	Episodic-Epiacidic
EQ	Sodosolic
ER	Stratic
ES	Subnatric
ET	Subplastic
EU	Sulfidic

CODE	NAME
EV	Sulfuric
EW	Supratidal
EX	Vertic
EY	Humose-Bleached
EZ	Melacic-Bleached
FA	Siliceous^
FB	Supracalcic
FC	Melanic-Calcareous
FD	Natric
FE	Ferrosols
FF	Submelacic
FG	Submelanic
FH	Palic@
FI	Ochric^
FJ	Hypergypsic
FK	Ferric-Duric
FL	Gypsic-Subplastic
FM	Epicalcareous-Epihypersodic
FN	Mottled-Subnatric
FO	Mottled-Mesonatric
FP	Mottled-Hypernatric
FQ	Dermosolic
FR	Kandosolic
FS	Terric
FT	Humose-Basic^
FU	Melacic-Basic
FV	Melanic-Acidic
FW	Faunic
FX	Lutaceous
FY	Epicalcareous
FZ	Endocalcareous
GA	Epiacidic
GB	Epicalcareous-Endohypersodic
GC	Melacic-Reticulate
GD	Peaty-Placic

CODE	NAME
GE	Ferric-Petroferric
GF	Regolithic
GG	Episodic-Endoacidic
GH	Episodic-Epicalcareous
GI	Episodic-Endocalcareous
GJ	Epicalcareous-Endoacidic
GK	Epiacidic-Mottled
GL	Endoacidic-Mottled
GM	Endocalcareous-Endohypersodic
GN	Epihypersodic-Endoacidic
GO	Epihypersodic-Endocalcareous
GP	Magnesic-Natric
GQ	Episodic-Gypsic
GR	Rudosolic
GS	Epipedal
GT	Tenosolic
GU	Humose-Calcareous
GV	Lutic
GW	Ferric-Acidic
GX	Manganic-Acidic
GY	Humose-Acidic
GZ	Bleached-Orthic^
HA	Melanic-Sodic
HB	Mottled-Sodic
HC	Ferric-Sodic
HD	Rudaceous
HE	Endocalcareous-Mottled
HF	Tephric
HG	Carbic
HH	Clastic
HI	Colluvic
HJ	Lithosolic
HK	Supravescent
HL	Episulfidic
HM	Episulfidic-Petrocalcic
HN	Densic-Placic

CODE	NAME
HO	Acidic-Sodic
HP	Palic-Acidic^
HQ	Ochric-Acidic^
HR	Cumulic
HS	Hortic
HT	Garbic
HU	Urbic
HV	Dredgic
HW	Spolic
HX	Scalpic
HY	Hydrosol
HZ	Ashy^
IA	Inceptic
IB	Epibasic
IC	Ceteric
ID	Subpeaty
IE	Effervescent
IF	Folic
IG	Humosesquic/Sesquic
IH	Humic/Alsilic
IJ	Modic
IK	Histic-Sulfidic^
IL	Sesqui-Nodular*
IM	Calcenic*
IN	Red-Orthic^
IO	Brown-Orthic^
IP	Yellow-Orthic^
IQ	Grey-Orthic^
IR	Black-Orthic^
IS	Ferric-Reticulate*
IT	Fusic+
IU	Subtidal+
IV	Subaqueous+
IW	Monosulfidic-Sulfuric+
IX	Monohypersulfidic+

CODE	NAME
IY	Histic-Hypersulfidic+
IZ	Hypersulfidic+
JA	Monohyposulfidic+
JB	Histic-Hyposulfidic+
JC	Hyposulfidic+
JD	Aquic-Sulfuric+
JE	Aquic-Hypersulfidic+
JF	Ferric-Endohypersodic+
JG	Manganic-Endohypersodic+
JH	Ferric-Endocalcareous+
JI	Manganic-Endocalcareous+
JK	Subhalic#
JL	Tenic#
JM	Arenosolic#
JN	Calsilic#
JP	Kandic#
JQ	Gritty#
JR	Gravic#
JT	Carbonatic#
JU	Coquinic#
JV	Gritty-Silpanic#
JW	Gritty-Lithic#
JX	Gritty-Paralithic#
KA	Kandosols
KU	Kurosols
OR	Organosols
PO	Podosols
RE	Arenosols
RU	Rudosols
SO	Sodosols
TE	Tenosols
VE	Vertosols
YY	Class Undetermined
ZZ	No Available Class

Table A2. Family criteria codes

introduced in third edition

WATER REPELLENCE	
NR	Non water repellent#
WR	Water repellent#
SR	Strongly water repellent#
A OR A1 HORIZON THICKNESS	
A	Thin
B	Moderately thick
C	Thick
D	Very thick
GRAVEL OF SURFACE AND A1 HORIZON	
E	Non gravelly
F	Slightly gravelly
G	Gravelly
H	Moderately gravelly
I	Very gravelly
A1, O2, P1 or P2 HORIZON TEXTURE	
J	Peaty
K	Sandy
L	Loamy
M	Clay loamy
N	Silty
O	Clayey
TEXTURE OF THE LAYER DIRECTLY UNDERLYING THE DEEPEST ORGANIC MATERIALS	
Z	Material absent
K	Sandy
L	Loamy
M	Clay loamy
N	Silty
O	Clayey

B HORIZON MAXIMUM TEXTURE	
K	Sandy
L	Loamy
M	Clay loamy
N	Silty
O	Clayey
CLAY CONTENT (Vertosols only)	
Q	Fine
R	Medium fine
S	Very fine
SOIL DEPTH	
T	Very shallow
U	Shallow
V	Moderately deep
W	Deep
X	Very deep
Y	Giant
–	Not Recorded
DOMINANT TEXURE OF THE UPPERMOST ORGANIC MATERIALS (O2, P1 OR P2)	
Z	Material absent
OA	Fibric peat#
OB	Hemic peat#
OC	Sapric peat#
OD	Sandy peat#
OE	Loam peat#
OF	Clayey peat#
NATURE OF ALTERED ORGANIC MATERIALS	
P	Granular
HZ	Ashy#
JZ	Vitric#

Appendix 3: Class names and equivalent codes, and the level at which they occur in the Soil Orders

CLASS	CODE	CLASS	CODE	CLASS	CODE
Anthroposols	AN	Ferrosols	FE	Podosols	PO
Arenosols	RE	Hydrosols	HY	Rudosols	RU
Calcarosols	CA	Kandosols	KA	Sodosols	SO
Chromosols	CH	Kurosols	KU	Tenosols	TE
Dermosols	DE	Organosols	OR	Vertosols	VE

SO = Suborder, GG = Great Group, SG = Subgroup; Family criteria excluded

Class	Code	AN	CA	CH	DE	FE	HY	KA	KU	OR	PO	RE	RU	SO	TE	VE
Acidic	AI				SG	SG	SG	SG		GG		SG	SG		SG	
Acidic-Mottled	AJ				SG			SG								
Acidic-Sodic	HO				SG		SG	SG								
Aeric	AL										SO					
Andic	AK							GG				GG			GG	
Aquic	AM										SO					SO
Aquic-Hypersulfidic	JE										SO					
Aquic-Sulfuric	JD										SO					
Arenaceous	BV						GG									
Arenic	AO												SO		GG	
Arenosolic	JM						GG									
Argic	AP		GG					SG				GG			GG	
Argillaceous	AQ						GG									
Basic	AR									GG		SG	SG		SG	
Bauxitic	AS							SG				GG	GG		GG	
Black	AE			SO	SO	SO		SO	SO			SO		SO	SO	SO
Bleached	AT			SG	SG		SG	SG	SG			SO			SO SG	SG
Bleached-Acidic	AU				SG		SG	SG								
Bleached-Ferric	AV			SG	SG		SG	SG	SG							
Bleached-Leptic	AW														SO	
Bleached-Magnesic	AX						SG									

Class	Code	AN	CA	CH	DE	FE	HY	KA	KU	OR	PO	RE	RU	SO	TE	VE
Bleached-Manganic	AY			SG	SG		SG	SG	SG						SG	
Bleached-Mottled	AZ			SG	SG			SG	SG							
Bleached-Sodic	BA			SG	SG		SG	SG	SG							
Bleached-Vertic	BB			SG	SG		SG		SG							
Brown	AB			SO	SO	SO		SO	SO			SO		SO	SO	SO
Calcareous	BC					GG	SG			GG		SG	SG		SG	
Calcarosolic	CB						GG									
Calcenic	IM														SO	
Calcic	BD		SO	GG	GG			GG				GG		SG		
Calsilic	JN											SO				
Carbic	HG												SO			
Carbonatic	JT		SO									SO				
Ceteric	IC		SG													
Chernic	BE											SO			SO	
Chernic-Leptic	BF														SO	
Chromosolic	BG						GG									
Clastic	HH												SO			
Colluvic	HI												GG			
Coquinic	JU												GG			
Crusty	BH															GG
Cumulic	HR	SO														
Densic	BI										SG					
Densic-Placic	HN										SG					
Dermosolic	FQ						GG									
Dredgic	HV	SO														
Duric	BJ		GG	GG	GG			GG				GG	GG	GG	GG	SG
Dystrophic	AF			GG	GG	GG	SG	GG	GG					SG		
Effervescent	IE			SG										GG		
Endoacidic	BL															SG
Endoacidic-Mottled	GL															SG
Endocalcareous	FZ															SG
Endocalcareous-Endohypersodic	GM															SG
Endocalcareous-Mottled	HE															SG
Endohypersodic	BP		SG													SG
Epiacidic	GA															SG
Epiacidic-Mottled	GK															SG

Class	Code	AN	CA	CH	DE	FE	HY	KA	KU	OR	PO	RE	RU	SO	TE	VE
Epibasic	IB		SG									GG				
Epicalcareous	FY						GG									SG
Epicalcareous-Endoacidic	GJ															SG
Epicalcareous-Endohypersodic	GB															SG
Epicalcareous-Epihypersodic	FM															SG
Epihypersodic	BR		SG													SG
Epihypersodic-Endoacidic	GN															SG
Epihypersodic-Endocalcareous	GO															SG
Epihypersodic-Epiacidic	CU															SG
Epipedal	GS															GG
Episodic	BN															SG
Episodic-Endoacidic	GG															SG
Episodic-Endocalcareous	GI															SG
Episodic-Epiacidic	EP															SG
Episodic-Epicalcareous	GH															SG
Episodic-Gypsic	GQ															SG
Episulfidic	HL						SG									
Episulfidic-Petrocalcic	HM						SG									
Eutrophic	AH			GG	GG	GG	SG	GG	GG					SG		
Extratidal	BT						SO									
Faunic	FW						GG									
Ferric	BU			SG	SG	SG	SG	SG	SG		SG	GG	GG	SG	GG	SG
Ferric-Acidic	GW				SG	SG	SG	SG								
Ferric-Duric	FK											GG			GG	
Ferric-Endocalcareous	JH															SG
Ferric-Endohypersodic	JF															SG
Ferric-Petroferric	GE											GG	GG		GG	
Ferric-Reticulate	IS											GG			GG	
Ferric-Sodic	HC			SG	SG		SG	SG								
Fibric	BW						SG			SO						
Fluvic	BX												GG			

Class	Code	AN	CA	CH	DE	FE	HY	KA	KU	OR	PO	RE	RU	SO	TE	VE
Folic	IF									GG						
Fragic	BY										SG					
Fusic	IT	SO					SG									
Garbic	HT	SO														
Gravic	JR											GG				
Grey	AD			SO	SO	SO		SO	SO			SO		SO	SO	SO
Gritty	JQ											GG	GG		GG	
Gritty-Lithic	JW														GG	
Gritty-Paralithic	JX														GG	
Gritty-Silpanic	JV														GG	
Gypsic	BZ		SG	SG	SG		GG					GG	GG	SG		SG
Gypsic-Subplastic	FL		SG													
Halic	CC						GG					GG	GG			
Haplic	CD			SG	SG	SG	GG	SG	SG							SG
Hemic	CE						SG			SO						
Histic	CF						GG									
Histic-Hypersulfidic	IY						GG									
Histic-Hyposulfidic	JB						GG									
Hortic	HS	SO														
Humic	CG										GG					
Humic/Alsilic	IH										GG					
Humic/Humosesquic	CI										GG					
Humic/Sesquic	CJ										GG					
Humose	CK			SG	SG	SG	SG	SG	SG		SG	SG		SG	SG	
Humose-Acidic	GY				SG	SG	SG	SG				SG			SG	
Humose-Bleached	EY			SG			SG		SG							
Humose-Calcareous	GU						SG					SG			SG	
Humose-Magnesic	CL						SG									
Humose-Mottled	CM			SG	SG			SG								
Humose-Parapanic	CN										SG					
Humosesquic	CO										GG					
Humosesquic/Sesquic	IG										GG					
Hypercalcic	CQ		SO	GG	GG			GG				GG		SG	SG	
Hypergypsic	FJ		SO									SO	SO			
Hypernatric	CR													GG		
Hypersalic	CS						SO					SO	SO			

Class	Code	AN	CA	CH	DE	FE	HY	KA	KU	OR	PO	RE	RU	SO	TE	VE
Hypersulfidic	IZ						GG			GG		GG	GG			SG
Hypervescent	CP		SG									GG				
Hypocalcic	CV		SO	GG	GG			GG				GG		SG		
Hyposulfidic	JC						GG			GG		GG	GG			SG
Inceptic	IA											GG			GG	
Intertidal	CW						SO									
Kandic	JP											GG				
Kandosolic	FR						GG									
Kurosolic	CX						GG									
Leptic	CY					GG		GG					SO		SO	
Lithic	CZ		GG							SG		GG	GG		GG	
Lithocalcic	DA		SO	GG	GG			GG				GG		SG	SG	
Lithosolic	HJ												GG			
Lutaceous	FX						GG									
Lutic	GV												SO			
Magnesic	DB			GG	GG	GG	SG	GG	GG					SG		SG
Magnesic-Natric	GP						SG		GG							
Manganic	DC			SG	SG	SG	SG	SG	SG			GG		SG	SG	SG
Manganic-Acidic	GX				SG		SG	SG								
Manganic-Endocalcareous	JI															SG
Manganic-Endohypersodic	JG															SG
Marly	DD		GG							SG		GG			GG	
Massive	DF															GG
Melacic	DG			SG	SG	SG	SG	SG	SG		SG	SG			SG	
Melacic-Basic	FU											SG			SG	
Melacic-Bleached	EZ						SG		SG							
Melacic-Magnesic	DH						SG									
Melacic-Mottled	DI			SG	SG			SG								
Melacic-Parapanic	DJ										SG					
Melacic-Reticulate	GC				SG											
Melanic	DK		SG	SG	SG	SG	SG	SG	SG		SG	SG		SG	SG	
Melanic-Acidic	FV				SG	SG	SG	SG				SG			SG	
Melanic-Bleached	DL						SG									
Melanic-Calcareous	FC											SG			SG	
Melanic-Mottled	DM			SG	SG	SG		SG								
Melanic-Sodic	HA				SG											
Melanic-Vertic	DN		SG	SG	SG		SG		SG					SG		

Class	Code	AN	CA	CH	DE	FE	HY	KA	KU	OR	PO	RE	RU	SO	TE	VE
Mellic	DO							GG								
Mesonatric	DP													GG		
Mesotrophic	AG			GG	GG	GG	SG	GG	GG					SG		
Modic	IJ									SG						
Monohypersulfidic	IX						GG			GG		GG	GG			SG
Monohyposulfidic	JA						GG			GG		GG	GG			SG
Monosulfidic-Sulfuric	IW						GG			GG		GG	GG			SG
Mottled	DQ			SG	SG	SG	GG	SG	SG							SG
Mottled-Hypernatric	FP													GG		
Mottled-Mesonatric	FO													GG		
Mottled-Sodic	HB			SG	SG			SG	SG							
Mottled-Subnatric	FN													GG		
Natric	FD						SG		GG							
Oxyaquic	DT						SO									
Palic	FH											GG				
Paralithic	DU		GG							SG		GG	GG		GG	
Parapanic	DV										SG					
Peaty	DW			SG			SG				SG	SG			SG	GG
Peaty-Parapanic	DX										SG					
Peaty-Placic	GD						SG				SG					
Pedal	DY		GG													
Pedaric	BK			GG	GG									GG		
Petrocalcic	DZ		GG	GG	GG		SG	GG				GG	GG	GG	GG	SG
Petroferric	EA			GG	GG		GG	GG	GG			GG	GG	GG	GG	
Pipey	EB										GG					
Placic	EC							GG		SG	SG				GG	
Red	AA			SO	SO	SO		SO	SO			SO		SO	SO	SO
Redoxic	ED						SO									
Regolithic	GF		GG							SG		GG	GG		GG	
Rendic	EE		GG													
Reticulate	EF			SG	SG		SG	SG	SG			GG			GG	
Rudaceous	HD									SG						
Rudosolic	GR						GG									
Salic	EG						SO									SG
Sapric	EH						SG			SO						
Scalpic	HX	SO														
Self-mulching	EI															GG

Class	Code	AN	CA	CH	DE	FE	HY	KA	KU	OR	PO	RE	RU	SO	TE	VE
Semiaquic	EJ										SO					
Sesquic	EK										GG					
Sesqui-Nodular	IL														SO	
Shelly	EL												SO			
Silpanic	EM						SG				SG	GG	GG	SG	GG	
Snuffy	EN					SG										
Sodic	EO			SG	SG	SG	SG	SG	SG							
Sodosolic	EQ						GG									
Spolic	HW	SO														
Stratic	ER											SO	SO			
Subaqueous	IV						SO									
Subhalic	JK											GG				
Subhumose	DR														SG	
Submelacic	FF														SG	
Submelanic	FG														SG	
Subnatric	ES													GG		
Subpeaty	ID											SG			SG	
Subplastic	ET		SG	GG	GG											
Subtidal	IU						SO									
Sulfidic	EU						GG			GG		GG	GG			SG
Sulfuric	EV						GG			GG		GG	GG			SG
Supracalcic	FB		SO	GG	GG			GG				GG		SG	SG	
Supratidal	EW						SO									
Supravescent	HK		SG													
Tenic	JL											GG				
Tenosolic	GT						GG									
Tephric	HF											GG	GG		GG	
Terric	FS									SG						
Urbic	HU	SO														
Vertic	EX		SG	SG	SG		SG		SG					SG		
Yellow	AC			SO	SO	SO		SO	SO			SO		SO	SO	SO

Appendix 4: Analytical requirements for the Australian Soil Classification

Arenosols	May need particle size analysis to determine % clay and confirm loamy fine sand and light sandy loam textures. May need particle size analysis to determine Kandic, Tenic and Palic Great Groups. May need % carbonate analysis of *fine earth* to confirm Suborder.
Calcarosols	Use of ESP at Subgroup level. May need particle size analysis to determine % clay to exclude sand textures. May need particle size analysis to determine % clay and confirm loamy fine sand and light sandy loam textures. May need % carbonate analysis of *fine earth* to confirm Carbonatic Suborder.
Chromosols	ESP will probably be needed for the upper 0.2 m of the B2 horizon to define the Order, and cations at Great Group level for the major part of the B2 horizon unless the B or BC horizon is calcareous or contains a *calcareous horizon*. For Subgroups, possible need for organic carbon or LOI (*loss-on-ignition*) to identify a humose horizon. Possible need for ESP in the lower part of the B horizon.
Dermosols	As for Chromosols except for ESP in the upper 0.2 m of the B2 horizon.
Ferrosols	Probable need for free Fe if soil is not definitely formed on basalt, otherwise as for Chromosols although few soils are yet known with sodic Subgroups.
Hydrosols	For some Suborders it may be useful to have water table conductivity. Some Great Groups of some Suborders may require ESP of the upper 0.2 m of any *clear or abrupt textural B horizon*. At the Subgroup level organic carbon or LOI may be required to identify peaty or humose horizons, and cations may be required to identify *base status*, Ca/Mg ratio and ESP of the B2 horizon.
Kandosols	As for Dermosols. May need particle size analysis to determine % clay and exclude light sandy loam textures.
Kurosols	At Great Group level ESP will probably be needed in the upper 0.2 m of the B2 horizon and cations in the major part of the B2 horizon. At the Subgroup level, as for Chromosols.
Organosols	Organic carbon or LOI.
Podosols	Possible need for organic carbon or LOI to identify peaty or humose horizons.
Rudosols	Possible need for conductivity at Suborder level.

Sodosols	ESP in the upper 0.2 m of the B2 horizon is needed to define the Order and the Great Groups. Cations required at the Subgroup level in the major part of the B2 horizon unless the B or BC horizon is *calcareous* or contains a *calcareous horizon*. Possible need for organic carbon or LOI to identify a humose horizon.
Tenosols	Organic carbon or LOI may be required at Suborder level to identify peaty or humose horizons.
Vertosols	ESP required at the Subgroup level in 0.1 m and also cations at depths above and below 0.5 m. Water table conductivity may also be required in some soils. Particle size analysis will be required at the Family level to determine clay content. Possible need for organic carbon or LOI to identify peaty horizons.

Note that pH has not been listed above because it may be estimated in the field. Similarly, it is not essential to have particle size analysis to determine whether or not a soil has a clear or abrupt textural B horizon.

Appendix 5: Approximate correlations between the Australian Soil Classification Orders and other soil classifications

Australian Soil Classification	Great Soil Group	Factual Key	Soil Taxonomy	WRB
	Stace *et al*. (1968)	Northcote (1979)	Soil Survey Staff (2014)	World Reference Base (2015)
Anthroposols	No equivalent	No equivalent	No equivalent or HAHT soils[1]	Anthrosols, Technosols
Arenosols	Siliceous sands, some earthy sands, calcareous sands, alluvial soils	Many Uc soils	Some Entisols	Arenosols, Regosols
Calcarosols	Solonised brown soils, grey-brown and red calcareous soils	Gc1, Gc2, Um1, Um5 soils	Aridisols, Alfisols	Calcisols
Chromosols	Non-calcic brown soils, some red-brown earths and a range of podzolic soils	Many forms of duplex (D) soils	Alfisols, some Aridisols	Abruptic Luvisols/ Lixisols
Dermosols	Prairie soils, chocolate soils, some red and yellow podzolic soils	Wide range of Gn3 soils, some Um4	Mollisols, Alfisols, Ultisols	Wide range of Reference Soil Groups including Chernozems, Phaeozems, Luvisols and Lixisols
Ferrosols	Krasnozems, euchrozems, chocolate soils	Gn3, Gn4, Uf5, Uf6 soils	Oxisols, Alfisols	Nitisols, Lixisols, some Ferralsols
Hydrosols	Humic gleys, gleyed podzolic soils, solonchaks and some alluvial soils	Wide range of classes, Dg and some Uf6 soils probably most common	Aquasols,[2] Ultisols, Inceptisols, salic Aridisols, Histosols	Gleysols, Stagnosols, Stagnic or Gleyic Vertisols/ Fluvisols, Solonchaks
Kandosols	Red, yellow and grey earths, calcareous red earths	Gn2, Um5 soils	Alfisols, Ultisols, Aridisols	Ferralsols, Luvisols, Lixisols
Kurosols	Many podzolic soils and soloths	Many strongly acid duplex soils	Ultisols, Alfisols	Abruptic Acrisols/ Lixisols/Alisols

Australian Soil Classification	Great Soil Group	Factual Key	Soil Taxonomy	WRB
	Stace *et al.* (1968)	Northcote (1979)	Soil Survey Staff (2014)	World Reference Base (2015)
Organosols	Neutral to alkaline, and acid peats	Organic (O) soils	Histosols	Histosols
Podosols	Podzols, humus podzols, peaty podsols	Many Uc2, some Uc3, Uc4 soils	Spodosols, some Entisols	Podzols
Rudosols	Lithosols, alluvial soils, some solonchaks	Uc1, Um1, Uf1, soils	Entisols, salic Aridisols	Leptosols, Fluvisols, Arenosols, Solonchaks
Sodosols	Solodized solonetz and solodic soils, some soloths and red-brown earths, desert loams	Many duplex (D) soils	Alfisols, Aridisols	Solonetz, Abruptic Luvisols, Planosols
Tenosols	Lithosols, some siliceous and earthy sands, alpine humus soils and some alluvial soils	Many Uc and Um soils	Inceptisols, Aridisols, Entisols	Cambisols, Leptosols, Plinthosols
Vertosols	Black earths, grey, brown and red clays	Ug5 soils	Vertisols	Vertisols

[1] Human-altered and human-transported (HAHT) soils and materials
[2] Proposed for the 13th edition
This table is intended only to give an idea of soils that approximately correspond to the Orders of the scheme. It is not meant to be used as an accurate translation between the various classification schemes. In many cases only major nearest equivalents can be given as differentiating criteria often differ between the four systems.

Appendix 6: History of the development of the Australian Soil Classification

Activities that led to the *Australian Soil Classification* commenced in 1981, when the Soil and Land Resources Committee (SLRC, then a sub-committee of the Standing Committee on Soil Conservation – SCSC) recommended the formation of a working party to look into the need for and the options for improving soil classification in Australia. In 1982 a questionnaire on the subject was sent to all members of the Australian Soil Science Society, the results of which were published (Isbell 1984). The working party (Ray Isbell, Pat Walker, David Chittleborough, Robert van de Graaff, Ron McDonald) recommended to the SCSC (via the SLRC) in 1984 that a soil classification committee be established under the auspices of SLRC to formulate a proposal for the establishment of a new or revised *Australian Soil Classification*. The working party also listed various options for this task, and provided several guiding principles.

The soil classification committee was formally endorsed by the SCSC early in 1985, with the following membership: Ray Isbell (Convener), David Chittleborough (SA), Alex McBratney (QLD), Ron McDonald (QLD) and Brian Murphy (NSW). Ian Sargeant (VIC) joined early in 1986.

The committee first met in August 1985 in Brisbane – Ken Day (NT) also attended. This meeting endorsed, with some amendment, the guiding principles of the earlier working party, and examined the various options available for a new or revised classification, particularly in the light of the replies of the earlier questionnaire.

The various options considered were:

1. Revision of the existing Stace *et al*. (1968) great soil group scheme. This was not considered practical but the scheme could be partly used as a basis for the preferred option.
2. Revision of the Factual Key (Northcote 1979). This was not practical given the structure of the classification. Also, it cannot strictly be considered as a general purpose scheme given the limited nature of the attributes used. However, appropriate features of the system could be incorporated into any new classification scheme.

3. Adoption of an overseas scheme, for example *Soil Taxonomy* (Soil Survey Staff 1975) or FAO-UNESCO (1990). The database on which these schemes were constructed related mostly to northern hemisphere temperate zone soils, therefore, it could not be expected that these would be the most appropriate for Australian soils. Experience has shown this to be true.
4. Adaptation of an overseas scheme to Australian needs and conditions. This was thought to be quite impractical and would also lead to confusion.
5. Development of a computer-based numerical system. Although some experiments had been conducted, no such scheme had yet been developed on a national basis anywhere in the world. Although techniques were becoming available, the lack of standardised data was to continue to be a problem for the foreseeable future.

During and following the 1985 committee meeting, attempts were made to establish likely diagnostic horizons, and existing classes of Australian soils – for example, Stace *et al*. (1968) Great Soil Groups and some Factual Key classes – were grouped into provisional new classes at various hierarchical levels. A meeting in July 1986 devoted particular attention to the question of creating classes using numerical methods. Subsequent exercises using the computer-based fuzzy set techniques developed by Alex McBratney were tried. Although this method had merit, an insurmountable problem at the time was the lack of an adequate representative dataset.

The selected option for a new Australian classification system was for a multi-categoric scheme with classes defined on the basis of diagnostic features and their arrangement in vertical sequence as seen in an exposed soil profile, rather than geographic attributes were to be used. In the new scheme, classes are based on real soil bodies, they are mutually exclusive, and the allocation of 'new' or 'unknown' individuals to the classes is by means of a key.

In March 1987, a preliminary version of the classification was sent to 25 pedologists around Australia for comment. The many useful replies were considered by the Committee at a meeting in Sydney in July 1987. Due to lack of any funding arrangements, no formal meetings of the Soil Classification Committee took place until it was reconstituted through the Working Group on Land Resource Assessment and the Australian Collaborative Land Evaluation Program in the early 1990s.

In late 1989, a 'First Approximation' of the scheme was issued as an unpublished working document (CSIRO Division of Soils Technical Memorandum 32/1989). This was widely distributed to some 200 people throughout Australia – many as a result of requests. The period from late 1989 to late 1991 was devoted to extensive testing of the scheme, both in the field and by checking relevant publications, and to a lesser extent by interrogating the CSIRO Division of Soils databases.

A 'Second Approximation' issued in January 1992 was a very much expanded version of the earlier one. Although the number of Orders remained the same, one was dropped (Melanosols) and one added (Dermosols). The main reason for the omission was that the diagnostic surface horizon of Melanosols is too easily lost by erosion or modified by human action – a problem similarly encountered in the Mollisols of *Soil Taxonomy*. The other major change was the narrower definition of Ferrosols as soils with high iron contents.

The introduction of Dermosols catered for similar structured soils that lack high iron contents.

In August 1992, the Australian Soil Conservation Council formally endorsed the new classification and recommended its adoption by all States and Territories and its use in all future federally funded land resource inventory and research programs. During 1992–93, a National Landcare Program grant enabled extensive field travel around Australia, and provided for an assistant to carry out extensive testing of the classification via published data and unpublished material in databases.

The 'Third Approximation' (Isbell 1993) followed extensive testing during 1992, both in the field and by checking relevant publications and, in particular, the comprehensive Queensland Department of Primary Industries soil profile database. Over 300 copies of this version were distributed to individuals and organisations, as well as copies to the ~70 people actively engaged in soil survey activities in the various States at this time. During 1993 the increased testing activity (including field workshops) resulted in three sets of amendments being distributed. In 1994, testing continued via published soil profile descriptions and other databases, and frequency distribution tables for all hierarchical levels of the classification were derived from the database. These enabled an assessment of the relative importance of the various classes, in particular at the Subgroup level.

The testing procedure

The creation and revision of a soil classification scheme essentially involves the erection of a tentative framework and testing it, preferably in the field but also via profile descriptions. The basic test for any classification is that the variance within classes must be less than that between them. Perhaps the simplest test is to see if you end up with very different soils in the same pigeon hole, with only the keying properties in common. In all classification schemes it is hoped, sometimes assumed, that there is a degree of covariance between the keying diagnostic features and those you wish to predict. Unfortunately, experience has shown that the degree of covariance between some soil diagnostic features is either low or not well established. This particularly applies to prediction of various chemical and physical properties from conventional soil morphology.

The original testing procedure was one of continual modification leading hopefully to improvement, and although the diversity of Australian soils is probably finite, the law of diminishing returns also applied here. Over the period concerned Ray Isbell personally described and classified in the field in excess of 1000 profiles in all States. The use of these and soil profile descriptions in databases and in publications dating back mostly to the early 1940s enabled the creation of the original classification database of 14 000 profiles, many of which had accompanying laboratory data. The data gave a good indication of the representativeness or otherwise of the dataset used to test and modify the classification.

No data was recorded for Anthroposols.

In the first edition, there was an apparent bias towards Queensland, but this merely reflected the much greater availability of good quality soil profile data over many regions of this State. Considered on an area basis, the number of profiles classified per 1000 km^2 ranged from 17.5 for Australian Capital Territory to 0.6 for Western Australia, with Tasmania 7.2, Victoria 5.0, Queensland 3.8, New South Wales 2.8, South Australia 1.5 and Northern Territory 0.6. However, it was not so much a matter of how many, but how representative were the profiles classified.

At the time there were large areas of Australia for which little or no soil data were available. These included, in general terms, the Northern Territory south of Daly Waters, but excluding the area around Alice Springs. Similarly, data were also scarce in approximately the northern three-quarters of South Australia. In Western Australia there were large areas with little or no available data, essentially east of a very approximate line joining Esperance and Port Hedland, but excluding the Kimberley region, the Nullarbor Plain and the southern part of the Great Victoria Desert. All of these are arid, and thus the lack of data was not surprising. However, there were also unexpected areas where data was sparse in spite of relatively intensive land use, for example significant parts of the Murray–Darling Basin, although soil surveys were currently in progress.

The original data also reflected to some extent the distribution of certain major Australian soils. Thus the Calcarosols are most prominent in South Australia and the Vertosols in Queensland and New South Wales. The percentages of soils with accompanying laboratory data obviously reflect the agricultural importance of some soils, but this was often confounded by different preferences between States in relation to laboratory analyses.

In spite of some deficiencies shown up by this analysis, it was thought at the time that this sample of the Australian soil population was reasonably representative of Australian soils as a whole. Certainly it was much more so than the data available for earlier classification systems. Obviously more data would have been desirable for Anthroposols and Organosols, and to a lesser extent Podosols and Rudosols. Even so, it was thought that the available knowledge of these soils (with the exception of Anthroposols) was adequate for the purposes of classification. With regard to the large areas of arid Australia indicated above where knowledge was scanty, there was sufficient indication from adjoining regions that the major soils in these areas are likely to be dominated by Tenosols, Rudosols and Kandosols of a kind common elsewhere in the arid zone.

Since its publication in 1996, the *Australian Soil Classification* has been widely adopted and formally endorsed as the official national system. Responsibility for maintenance and updating now resides with the National Committee on Soil and Terrain (NCST). The NCST also oversaw the Australian Collaborative Evaluation Program (ACLEP). It published a supporting volume entitled *Concepts and Rationale of the Australian Soil Classification* (Isbell *et al*. 1997), a CD called *The Australian Soil Classification: An Interactive Key* (Jacquier *et al*. 2001), a revised edition of the classification in 2002 and a second edition in 2016.

Following recommendations by the Australian Soil Classification Working Group, in 2016 the NCST released a second edition to accommodate new knowledge and understanding of soils containing *sulfidic materials*. Included in these changes was the introduction of *subtidal* and *subaqueous* soils. Soils with abundant ironstone gravels were also accommodated by a Sesqui-Nodular Suborder in Tenosols.

This third edition (2021) introduces a new Order, the Arenosols, which represents the deep sands that were formerly classified as Tenosols, Rudosols and Calcarosols. These latter Orders have extreme morphological diversity and since the first edition have been subject to extensive investigation, particularly in South Australia, south-west Western Australia and the Northern Territory. The main changes to the third edition are described in Appendix 7.

Appendix 7: Summary of changes in the third edition

The main changes in the third edition accommodate existing knowledge and understanding of the significance, nature, distribution and refined testing for soils comprising deep sands. This involved the introduction of a new Order, the Arenosols. The introduction of the Arenosols Order also led to a review and changes to Calcarosols, Tenosols and Rudosols.

Another significant change is the removal of the *weakly developed* tenic B horizon concept from the classification. Experience shows the concept is of little assistance in soil classification. It is not explicitly defined and therefore cannot be consistently determined, limiting its value as a classification criterion.

The important points to note for the Orders affected, plus other improvements throughout the text, are summarised below:

Arenosols

a) Deep sands (sands at least 1.0 m deep) formerly classified as Calcarosols, Tenosols and Rudosols now classify as Arenosols.
b) Soils with >10% coarse fragments and/or hard segregations (by visual abundance and weighted average in the top 1.0 m) are excluded from the Arenosols Order.
c) Horizon development may be absent in some Arenosols previously described as Rudosols.
d) Some Podosols could be initially classified as Grey or Bleached Arenosols if investigation of the profile stops before reaching a diagnostic horizon (Bs, Bhs or Bh).
e) Deep sands with pedogenic carbonates previously classified as Shelly, Calcic or Hypocalcic Calcarosols will now classify as Carbonatic or Calsilic Arenosols.
f) The Tenosol Great Groups formed the basis of the Arenosol Great Groups but other forms are included. Additional Great Groups include Gritty (mainly granitic sands), Kandic (sandy loam B horizon with ~10–15% clay – soils transitioning to a Kandosol), Palic (clay <5%), Tenic (clay ~5–10%), Gravic (heavy mineral sands) and Subhalic, Hypocalcic, Lithocalcic, Supracalcic, Hypercalcic and Calcic.

g) Text in the How to Classify section provides tips on how to determine if a deep, more clayey horizon (often >1.0 m deep) is a B or D horizon. This helps in determining if the soil is an Arenosol or some other Order.

Calcarosols

a) In the 'Key to Soil Orders', the criteria for Calcarosols are changed to exclude deep sands.
b) The Shelly Suborder has been removed and replaced by the Carbonatic Suborder.

Ferrosols

a) A Leptic Great Group is added.

Hydrosols

a) An Arenosolic Great Group is added to the Extratidal, Salic, Redoxic and Oxyaquic Suborders.

Kandosols

a) The requirement in the definition of 'Do not have a tenic B horizon' is removed and the requirement in the 'Key to Soil Orders' for the B2 horizons to be 'well developed' is removed.
b) Andic and Leptic Great Groups are added.

Organosols

a) The Order definition now includes mineral horizons and unconsolidated mineral materials (no thicker than the organic materials above) to allow many shallow soils dominated by organic materials to be classified as Organosols.
b) Melanic horizon material is added to the Order definition.
c) The Suborder definitions reflecting peat dominance are modified to improve usefulness and clarity.
d) New data from Tasmania has necessitated the expansion of the Family criteria to six. The new criteria are: Nature of altered organic materials; Cumulative thickness of uppermost organic materials; Gravel of the surface horizon; Dominant texture of the uppermost organic materials; Texture of the layer directly underlying the deepest organic materials; and Soil depth.

e) The criteria Cumulative thickness of organic materials and Nature of uppermost organic materials have been removed.
f) The new Nature of altered organic materials Family criterion caters for soils modified by fire or drying. It includes the Fusic and Ashy diagnostic features that were formerly included at the Subgroup level, and the Granular diagnostic feature that was formerly included in the Nature of uppermost organic materials criterion.

Rudosols

a) The Shelly definition is amended to provide clarity.
b) Coquinic, Petrocalcic, Lithic and Regolithic Great Groups are included for Shelly Rudosols.
c) The Arenic definition is amended to be consistent with Arenosols.
d) The six Great Groups currently available for Leptic Rudosols are now available for Arenic Rudosols as well. Previously no Great Groups had been proposed for the Arenic Suborder.
e) The set of families available has been expanded from two to six and is now consistent with other Orders.
f) The Silpanic and Gritty Great Groups have been added to the Arenic and Leptic Suborders.

Tenosols

a) The term Orthic is now redundant and removed from Tenosol Suborders.
b) The concept of a tenic B horizon is removed.
c) The definition of the Calcenic Suborder is amended (i.e. from 'pedogenic carbonate' to 'fine earth carbonate').
d) For consistency, the Arenic Great Group is keyed out before Inceptic, Lithic, etc.
e) The definition of Arenic is amended to be compatible with Arenosols.
f) Shelly Tenosols are removed and classify as either Arenosols or Rudosols.
g) Various Gritty Great Groups are added.
h) The 13 Subgroups previously available for Bleached-Orthic are now available for the coloured Suborders as well, but four Subgroups (Subpeaty, Subhumose, Submelacic and Submelanic) are no longer available.
i) The Silpanic Great Group has been added to the Chernic-Leptic and Leptic Suborders.

Other changes

Other important, but less substantial, changes are incorporated into the third edition. These mainly aim to improve clarity and consistency, and also align with definitions in the *Australian Soil and Land Survey Field Handbook* (NCST 2009), referred to in this publication as the *Field Handbook* (the *Field Handbook* is also colloquially known as the Yellow book due to the colour of its cover).

a) An amended Fig. 1 to match the order in the 'Key to Soil Orders'.
b) Each Order is accompanied by a map of its distribution.
c) Where appropriate, 'B2' horizon is replaced by 'B2t'.
d) In the key, the term 'structure' is replaced by 'grade of pedality'.
e) 'Soft, finely divided carbonate' is replaced with 'fine earth carbonate'.
f) To improve clarification of terminology, the glossary is expanded with additional terms and definitions, including some from the *Field Handbook*.
g) Some definitions in the glossary are amended to align with the *Field Handbook*. In some cases the definitions are changed in both publications – these changes will be reflected in the next edition of the *Field Handbook*.
h) Colour classes are explained more fully, and digital versions contain a table in colour.
i) Confidence levels are rewritten for greater clarity.
j) Several new references are included and some older ones updated.
k) A water repellence Family criterion is added for surface soils of susceptible Orders.
l) Consistent use of metric units throughout the publication – millimetres for sizes/depths ≤0.1 m (e.g. 50 mm) and metres for sizes/depths ≥0.1 m (e.g. 0.5 m).
m) Guidance is now provided for soil classification at Great Group and Subgroup level where the diagnostic feature for a class begins more than 1.5 m below the soil surface.