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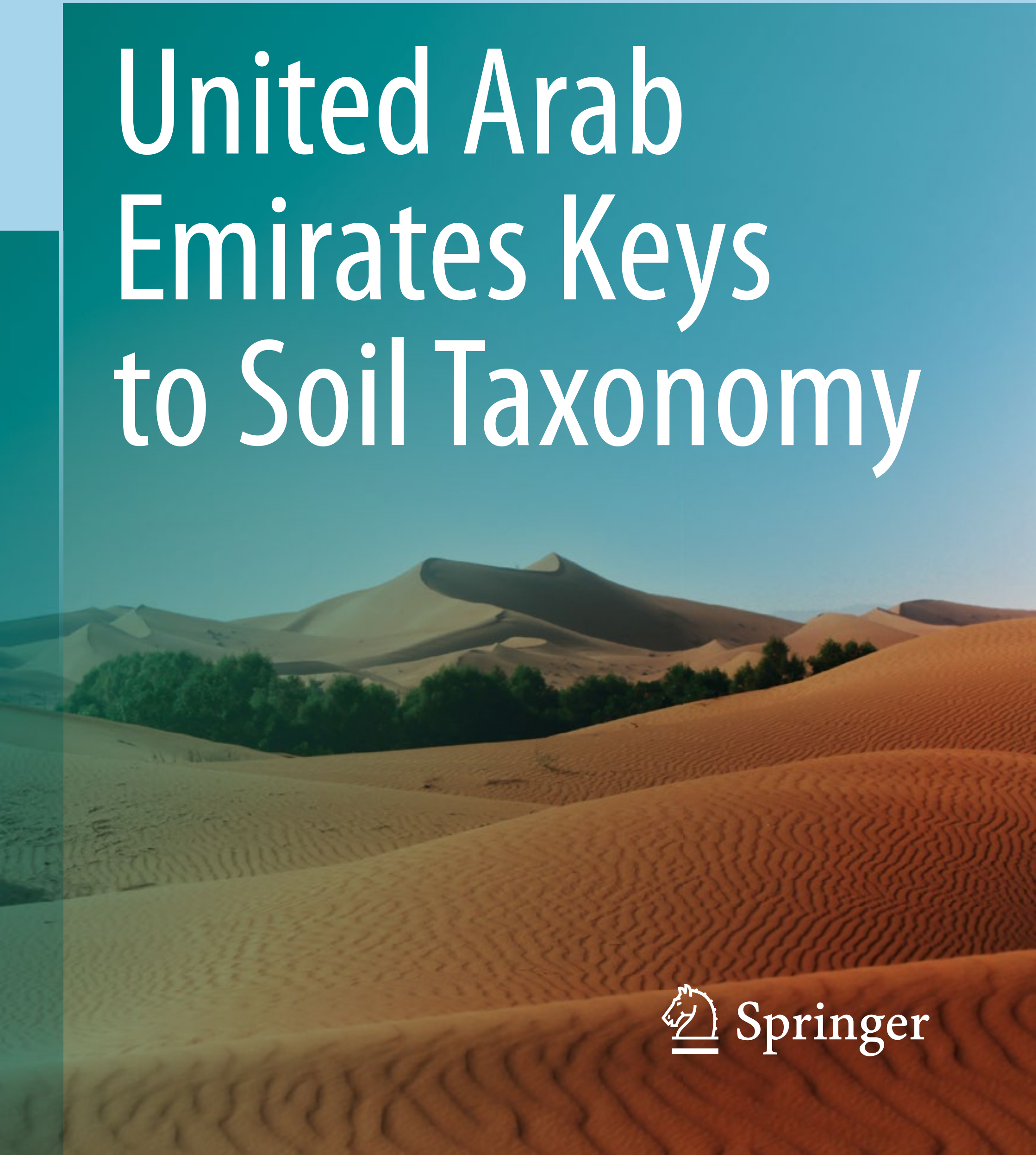
United Arab Emirates Keys to Soil Taxonomy



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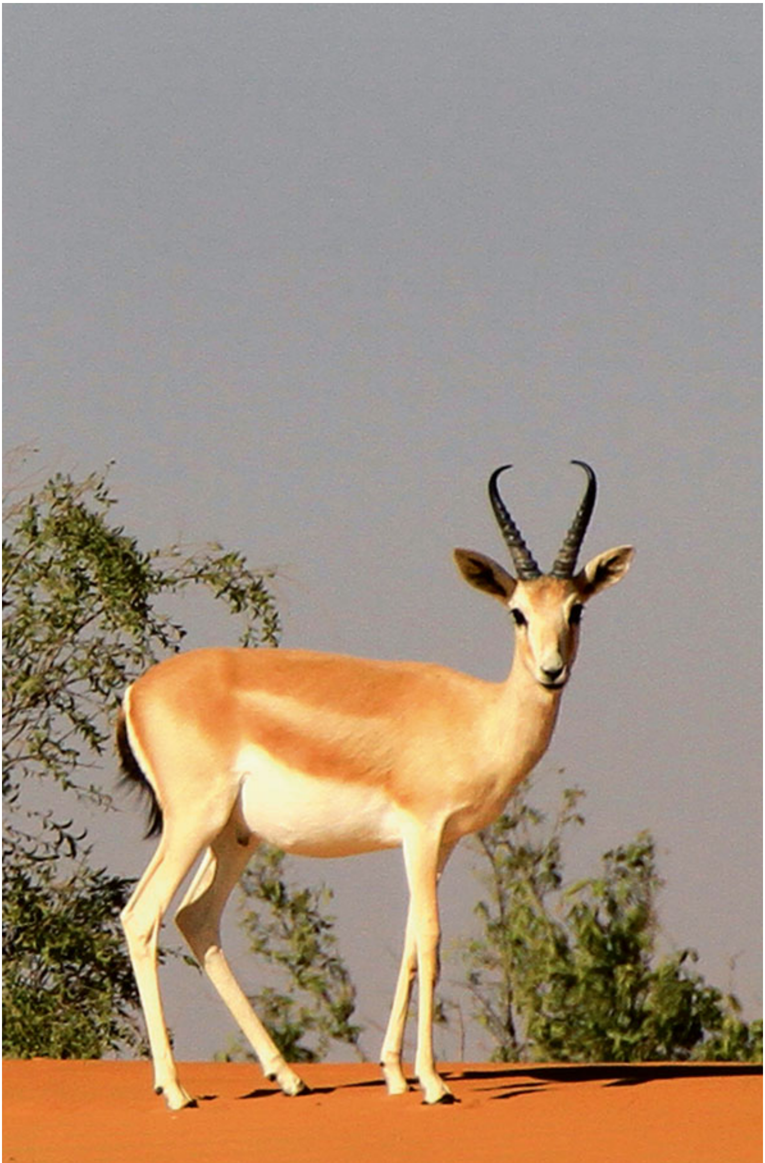

*Federal laws protect wildlife (Sand gazelle-gazelle subgutturosa)
in the UAE deserts*

Wetlands in the desert environment are attraction to Flamingo (Phoenicopterus ruber)

From ICBA Director General

The *United Arab Emirates Keys to Soil Taxonomy* is a cooperative effort of ICBA, EAD, and USDA-NRCS staff. This cooperation has been recognized by J. Cameron Loerch (National Leader, Soil Survey Standards, USDA-NRCS) which sets a way forward of cooperation between these organizations for many years to come. The development of this valuable piece of work is unique in the Arab region and the authors deserve special congratulations. The book specifically addresses soil taxonomy in the UAE; however, it is equally good for use in the Gulf States where Aridisols and Entisols are the major soil orders. I believe the soil researchers in future will be significantly benefitted from this valuable resource in their endeavor to assess soil resources in the UAE and the Gulf Region.

Dr. Ismahane A. Elouafi
Director General
International Center for Biosaline Agriculture, Dubai UAE

Proper management of sandy soils (Entisols) is a pre-requiste for desert farming

From EAD Secretary General

The *United Arab Emirates Keys to Soil Taxonomy* is an essential tool for further soil classification studies in the United Arab Emirates. The challenge of protecting and managing the environment is significant and must be based on robust scientific and technical knowledge. Knowledge and understanding of soil is critical, particularly in an arid environment, as the resources in soil are scarce and must answer competing demands from agriculture to urban development, mineral exploration, and infrastructure development. In this regard, many approaches have been developed to partition the national landscapes into meaningful soil units from classification and land use perspectives. This book will facilitate national land use management and planning and will be equally useful for agricultural graduates studying soil science. The authors are congratulated for this unique achievement.

Razan K. Al Mubarak
Secretary General
Environment Agency—Abu Dhabi

Flooded interdunal sabkha is common in the south of UAE, high dunes in the background is dominant landscape

From USDA-NRCS National Leader

The *United Arab Emirates Keys to Soil Taxonomy* provides a basic soil classification system that will prove to be very beneficial to anyone wishing to classify and correlate soils within the region. It not only provides the taxonomic key necessary for the classification of soils that can be easily used in the field, but establishes a scientific standard to be used (and updated as needed) for future generations. The authors are congratulated for this outstanding collaborative effort in developing a dynamic system that will serve current and future generations of soil scientists as they strive to better understand and educate the public about this vital natural resource *the soil*.

J. Cameron Loerch
National Leader, Soil Survey Standards
USDA-Natural Resources Conservation Service

Diversified landscape showing sandy soils and wetland in mountainous area of UAE

About the Associate Authors

Collectively from ICBA, EAD, and USDA-NRCS, the authors have brought a vast range of knowledge and experience together in the development of the *United Arab Emirates Keys to Soil Taxonomy*.

Dr. Shabbir A. Shahid has more than 32 years of experience as a Soil Scientist in Pakistan, UK, Australia, Kuwait, and the United Arab Emirates. He served as Lead Soil Taxonomist, Technical Coordinator, and QA Expert for the Soil Surveys of Kuwait (1996–1999) and Abu Dhabi Emirate (2004–2009). He with his co-associates discovered anhydrite soil in the coastal land of Abu Dhabi Emirate. He is a prolific author and coauthor of over 150 scientific papers published in peer-reviewed scientific journals, books, and manuals. He pioneered the concept of soil survey in the UAE.

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Dr. Mahmoud A. Abdelfattah served as a Mapping Crew Leader and Deputy Technical Coordinator for the Soil Survey of the Abu Dhabi Project (2004–2009) and Technical Manager for the Soil Survey of the Northern Emirates (2010–2012). He has over 20 years of experience in teaching and research. He has participated in a number of international conferences, managed a number of technical projects, and has authored and coauthored over 50 published scientific papers and book chapters.

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Mr. John A. Kelley has more than 33 years of experience as a USDA Soil Scientist and Regional Correlator in the eastern USA and served as Technical Coordinator and Quality Assurance Specialist for the Soil Survey of the Northern Emirates. He has contributed in many ways toward the completion of this key, serving as Technical Editor and helping with photography including photo editing and image processing.

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Mr. Joseph V. Chiaretti is a Soil Scientist with the USDA and serves on the soil survey standards staff at the NRCS National Soil Survey Center in Lincoln, Nebraska. He is responsible for developing and maintaining soil survey division handbooks and other technical documents. Prior to his current position, he has had 11 years of experience in conducting quality assurance on soil survey data and 19 years of experience in leading and field mapping on soil survey projects in the southwestern USA.

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Indepth exploration of a soil taxa in the coastal land of UAE

Preface

All terrestrial life ultimately depends on soil, energy, and water. Soils have always been central to human civilization and life. They are an integral part of the physical and cultural environment, and we may take them for granted and even tend to treat them contemptuously in the United Arab Emirates (UAE). The rise and fall of civilizations have been closely linked with the use and abuse of soil and water resources. There is little reason to believe that these linkages will disappear in the future. It is therefore important to evaluate soils for their quality and link them to appropriate uses and services. In this publication, information is provided on soil classification and how to key out taxa relevant to UAE soils.

The recent soil inventory of the United Arab Emirates revealed that the UAE landscape is covered mainly by low-lying sandy deserts, mega-barchan dunes, extensive coastal salt flats, and alluvial and gravelly plains in both the far west and the east. The recent soil surveys revealed that a rather uniform-looking desert landscape has, in fact, a diversity of subsurface features that help to categorize the soils into 74 soil series and their phases. These features confirm the soil diversity in terms of classification, chemistry, physics, mineralogy, fertility, suitability for different uses, and vulnerability to land degradation.

The objectives of this book are to provide information for keying out the soils of the United Arab Emirates into separate classes and to provide a guide to associated laboratory methods. The classification used predominantly is extracted from the 11th edition of the USDA-NRCS *Keys to Soil Taxonomy*, and sections relevant to the soils found in the UAE are included here.

Primarily, this key is designed to fit the soil system of the United Arab Emirates. Information not found in the USDA key has been added including criteria and classes for: (1) differentiating anhydritic soils from gypsic soils; (2) identifying "lithic" subgroups for Aquisalids and Haplosalids; (3) identifying "salidic" subgroups within the great groups of Gypsids, Calcids, Psamments, and Orthents; and (4) incorporation of phases for soil taxa. The classes for the newly identified anhydrite soils in the UAE have been added at four different levels: the *anhydritic* subsurface diagnostic horizon and mineralogy class and the *Anhydritic Haplosalids* and *Anhydritic Aquisalids* subgroups. In addition, a horizon suffix of "aa" for layers with an accumulation of anhydrite has been incorporated. The concept of horizon suffix "k" also has an ad hoc expansion, beyond the official definition of pedogenic accumulations, to connote the simple presence of calcium carbonate as determined by effervescence in dilute hydrochloric acid. This usage is synonymous with the recently defined soil characteristic named "free carbonates" in the *Keys to Soil Taxonomy*. The added classes or features that are proposed for USDA *Soil Taxonomy* are designated with a "†" in the Table of Contents and are footnoted in the text. The classes are in different stages of review and approval for use in the USDA soil taxonomy system; however, discussions regarding final approval and incorporation of the additions are ongoing. Other additions such as "Phases of soil taxa" are unique to the *United Arab Emirates Keys to Soil Taxonomy* and are not proposed for addition to the USDA system.

This book will provide a mechanism for updating the current soil surveys and will facilitate the correlation of soils from new surveys within the UAE. Additionally, this book provides a source of information to help the international soil science community converse about UAE soils and their comparison to other soils. Commonality between classification systems used in different countries enhances linkages. These linkages allow countries with similar mapping and classification procedures and similar soils to transfer agriculture technology without conducting long-term experiments under similar environmental conditions.

We hope the countless number of users of soil surveys in the UAE and abroad will use this publication to learn about classification of the soils of the United Arab Emirates.

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Team Leader, International Center for Biosaline Agriculture
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Surface gravel layer (armor layer) is an indicator of land degradation

Camel grazing is common in high sand dune area

Acknowledgements

The authors would like to thank both the management of the Dubai-based International Center for Biosaline Agriculture and the Environment Agency—Abu Dhabi for their partnership in the joint completion of the state-of-the-art Soil Survey of Abu Dhabi Emirate and preparation of the action plan for the Soil Survey of the Northern Emirates. The management of the UAE Ministry of Environment and Water and EAD deserve special thanks for the joint implementation of the Northern Emirates Soil Survey project. Special thanks to H.E. Mr. Majid Al Mansouri, former Secretary General of the Environment Agency—Abu Dhabi, H.E. Ms. Razan Khalifa Al Mubarak, EAD Secretary General, and H.E. Dr. Jaber Al Jaberi, EAD Deputy Secretary General, for their full support during the implementation of the Soil Survey of Abu Dhabi and the Soil Survey of the Northern Emirates, which this key is based upon.

The Australian contractor GRM International deserves special thanks for the completion of both surveys. The soil survey reports were used as the basis for the compilation of the *United Arab Emirates Keys to Soil Taxonomy*.

Special thanks go to Dr. Ismahane Elouafi (Director General ICBA) and Dr. Ahmed A. Al Sharif (Deputy Director General ICBA) for their encouragement and interest in completing this important publication that will be used by UAE nationals for many years ahead.

Associate Authors

Soil Scientists from ICBA, EAD, USDA-NRCS and CSIRO jointly visited newly discovered Anhydrite soil in Abu Dhabi Coastal land

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Soil Classification

1

Abstract

The global knowledge of soil classification is continually advancing; therefore, soil taxonomies are regularly upgraded as the new soils are identified. Presently, several soil classification systems are used worldwide. Most systems in use generally provide guidelines to key out soils within their national boundaries. Some examples are Soil Classification for England and Wales, the Soil Map Legend of the World, World Reference Base for Soil Resources, the Canadian System of Soil Classification, the Australian Soil Classification, the New Zealand Soil Classification and the Russian Soil Classification System. The US Soil Taxonomy is a comprehensive system to be used globally, and has been used extensively in over 75 countries. No one country has within its boundaries all the soils identified in any soils key: therefore the user in the UAE has to go through all the list of potential soils to key out a specific soil in the study area. This issue suggests a need to develop Keys to Soil Taxonomy addressing the soils within the national boundaries of any country; for example the UAE. The United Arab Emirates Keys to Soil Taxonomy is a collection of information from UAE soil surveys and is specifically useful at the national level, or for other Gulf Cooperation Council countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia) where these soils have been mapped in national soil inventories.

Keywords

Soil classification systems • Soil map • Soil taxonomy • UAE

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1.1 Introduction

Soil classification systematically arranges soils into groups or categories on the basis of their characteristics, whereas the soil survey is a systematic examination, description, classification, and mapping of soils in an area. The global knowledge of soil classification is continually advancing; therefore, soil taxonomies are continuously upgraded. Presently, several soil classification systems are used worldwide. Among these, *Soil Taxonomy* (Soil Survey Staff 1999) is very comprehensive and has been used extensively, including GCC countries (Saudi Arabia, Oman, Kuwait, Qatar, Abu Dhabi Emirate, Dubai Emirate, and the Northern Emirates of UAE). Other systems in use are Soil Classification for England and Wales (Avery 1980), the Soil Map Legend of the World (FAO-UNESCO 1990), World Reference Base for Soil Resources (WRB) (IUSS Working Group WRB 2006), the Canadian System of Soil Classification (Canadian Soil Survey Committee 1978), the Australian Soil Classification (Isbell 1998), the New Zealand Soil Classification (Hewitt 1992), and the Russian Soil Classification System (Shishov et al. 2004).

In the Dubai Emirate, soil taxonomy was used to classify soils at 1:25,000 scale at soil series level (DM 2005). In the Abu Dhabi Emirate, soil taxonomy was used to classify soils at two survey levels: (1) Extensive survey—a fourth order level modified to fit Abu Dhabi soil conditions at a scale of 1:100,000; and (2) Intensive survey—a second order level modified to fit Abu Dhabi soil conditions at a scale of 1:25,000 (EAD 2009a, b). The complete report consists of five volumes, including an Executive Summary. The soil survey of the Northern Emirates (EAD 2012) is a third order level soil survey conducted at a scale of 1:50,000. The complete report consists of three volumes including an Executive Summary.

The focus of this publication is to provide useful information to soil surveyors in the UAE, as well as other soil scientists around the world, to key out soils of the Emirates. The information provided in this book is principally based on the Dubai Emirate, Abu Dhabi and Northern Emirates soil surveys. However, in the future, more taxa will likely be added to this book as mapping and research recognize additional soils in the UAE. Thus, soil scientists and other users should classify the soils using the most recent version of *The United Arab Emirates Keys to Soil Taxonomy*.

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Agriculture farming on an interdunal plain at the base of megadunes

The Soils That We Classify

2

Abstract

Soil is the natural medium for the growth of land plants, whether or not it has discernible soil horizons. People consider soil important because it supports plants that supply food, fibers, drugs, and other human needs and because it filters water and recycles wastes. Soil is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occur on the land surface, occupies space, and is characterized by horizons, or layers, that are distinguishable from initial geologic material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment. The upper limit of soil is the boundary between soil and air, shallow water, live plants, or plant materials that have not begun to decompose. For purposes of classification, the lower boundary of soil is arbitrarily set at 200 cm. In areas where soil has thin cemented horizons that are impermeable to roots, the soil extends as deep as the deepest cemented horizon, but not below 200 cm.

The United Arab Emirates Keys to Soil Taxonomy is designed in such a way that the reader makes the correct classification by going through the key systematically, starting at the beginning and eliminating one by one all classes that include criteria that do not fit the soil or layer in question.

Keywords

Cemented horizons • Geological material • Land plants • Natural body • Lower boundary

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2.1 Introduction

This section in general is taken from *Keys to Soil Taxonomy* (Soil Survey Staff 2010) with slight modifications that reflect the soil conditions and the soil system in the United Arab Emirates.

Soil is the natural medium for the growth of land plants, whether or not it has discernible soil horizons. This meaning is still the common understanding of the term, and the greatest interest in soil is centered on this meaning. People consider soil important because it supports plants that supply food, fibers, drugs, and other wants of humans and because it filters water and recycles wastes. Soil is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occur on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from initial geologic material as a result of additions, losses, transfers, and transformations of energy and matter *or* the ability to support rooted plants in a natural environment. This definition is expanded from the 1975 version of *Soil Taxonomy* (USDA, SCS 1975) to include soils in areas of Antarctica where pedogenesis occurs but where the climate is too harsh to support the higher plant forms.

The upper limit of soil is the boundary between soil and air, shallow water, live plants, or plant materials that have not begun to decompose. Areas are not considered to have soil if the surface is permanently covered by water too deep (typically more than about 2.5 m) for the growth of rooted plants. The lower horizontal boundaries of soil are areas where the soil grades to deep water, barren areas, rock, or ice. In some places the separation between soil and nonsoil is so gradual that clear distinctions cannot be made.

The lower boundary that separates soil from the nonsoil underneath is most difficult to define. Soil consists of the horizons near the earth's surface that, in contrast to the underlying parent material, have been altered by the interactions of climate, relief, and living organisms over time. Commonly, soil grades at its lower boundary to hard rock or to earthy materials virtually devoid of animals, roots, or other marks of biological activity. The lowest depth of biological activity, however, is difficult to discern and is often gradual. For purposes of classification, the lower boundary of soil is arbitrarily set at 200 cm. In soils where either biological activity or current pedogenic processes extend to depths greater than 200 cm, the lower limit of the soil for classification purposes is still 200 cm (Fig. 2.1). In some instances the more weakly cemented bedrocks (paralithic materials) have been described and used to differentiate soil series (series control section), even though the paralithic materials below a paralithic contact are not considered soil in the true sense. In areas where soil has thin cemented horizons that are impermeable to roots, the soil extends as

Fig. 2.1 Soil scientists examining and describing a typical soil profile. The scientists document several soil properties and features, commonly to a depth of 2 m. Note the distinct change in horizons (or layers) with depth

deep as the deepest cemented horizon, but not below 200 cm. For certain management goals, layers deeper than the lower boundary of the soil that is classified (200 cm) must also be described if they affect the content and movement of water and air or other interpretative concerns.

2.2 Buried Soils

A buried soil is covered with a surface mantle of new soil material that either is 50 cm or more thick or is 30–50 cm thick and has a thickness that equals at least half the total thickness of the named diagnostic horizons that are preserved in the buried soil. A surface mantle of new material that does not have the required thickness for buried soils can be used to establish a map unit phase of the mantled soil or even another soil series if the mantle affects the use of the soil.

A surface mantle of new material, as defined here, is largely unaltered, at least in the lower part. It may have a diagnostic surface horizon (epipedon) and/or a cambic horizon, but it has no other diagnostic subsurface horizons, all defined later. However, there remains a layer 7.5 cm or more thick that fails the requirements for all diagnostic horizons, as defined later, overlying a horizon sequence that can be clearly identified as the solum of a buried soil in at least half of each pedon. The recognition of a surface mantle should not be based only on studies of associated soils. Soil, as defined in this text, does not need to have discernible horizons, although the presence or absence of horizons and their nature are of extreme importance in soil classification. Plants can be grown under glass in pots filled with earthy materials, such as peat or sand, or even in water. Under proper conditions all these media are productive for plants, but they are nonsoil here in the sense that they cannot be classified in the same system that is used for the soils of a survey area, county, or even a nation. Plants even grow on trees, but trees are regarded as nonsoil.

Soils are three dimensional (3-D) bodies, and many scientists have different opinions about the classification. From a soil classification point of view, however, the entity that is classified is the *soil profile*, which is a vertical section of soil through different horizon to the parent material. Soil has many properties that fluctuate with the seasons. It may be alternately cold and warm or dry and moist. Biological activity is slowed or stopped if the soil becomes too cold or too dry. The soil receives flushes of organic matter when leaves fall or grasses die. Soil is not static. The pH, soluble salts, amount of organic matter and carbon-nitrogen ratio, numbers of micro-organisms, soil fauna, temperature, and moisture all change with the seasons as well as with more extended periods of time. Soil must be viewed from both the short-term and long-term perspective.

Soils are (Shahid 2007):

- The essence of life
- A product of the environment
- Developed, and not merely an accumulation of debris from rocks and organic matter
- Different from the material from which they are derive
- Continuously changing due to natural and human influences
- Different in inherent capability
- The sites for chemical reactions and organisms
- A medium for the support of plants
- A medium for filtering water and recycling wastes
- Very fragile
- Very slowly renewable

The hierarchy of Dubai (DM 2005), Abu Dhabi (EAD 2009a, b; Shahid et al. 2004) and Northern Emirates soil classification (EAD 2012) has been used in the preparation of this book to help the new user assign soil taxonomic classifications in areas of his/her interest for the maintenance of soil surveys in the UAE. It is most likely that in the process of future soil surveys, new classifications will be identified. In the light of new findings, this edition will be updated periodically as needed.

2.3 Approach to Soil Classification

When classifying soils the user must first consider: (1) the depth in which the soil feature (property or characteristic) occurs; (2) the thickness of the layer where it occurs; and (3) the extent or degree of expression that the feature exhibits. Those soil properties that have a major influence for use and management of the soil are defined as diagnostic horizons. For the diagnostic subsurface horizons identified in the UAE to be recognized at the highest levels of classification (order, suborder, great group, or subgroup) they must occur within a depth of 100 cm from the soil surface. This is the predominant rooting depth of most plants commonly grown. If these features are present but occur at a lower depth (but within 200 cm) they still play an important role in land use planning and have been identified as phases.

Often the soil feature critical to classification is confirmed by simple observation (Fig. 2.2) and volume estimation (qualitative analysis). However, once the feature has been identified, laboratory support is commonly needed to quantify the amount or degree of expression to confirm classification. For example, the presence of calcium carbonate may be observed in the soil profile in the form of coatings, masses, or nodules and a subjective estimate (by volume) is made. However, to confirm the presence of a calcic horizon samples must be collected and analyzed and the presence of calcium carbonate determined quantitatively (by weight). The amount of the material, depth in which the material was observed, and the thickness of the horizon in which it occurs all go together to document the presence of the diagnostic horizon and subsequent taxonomic placement.

The *United Arab Emirates Keys to Soil Taxonomy* is designed in such a way that the reader makes the correct classification by going through the key systematically, starting at the beginning and eliminating one by one all classes that include criteria that do not fit the soil or layer in question. The key has been designed to provide separation of major soil features. In many sections the sequence of the key is based on the severity of limitation the particular property may pose.

Fig. 2.2 Any information collected at a soil description site is carefully documented and geo-referenced

2.4 Naming Subgroups

Subgroups are keyed in a specific and consistent order based on their limitation to use and management of the soils. Subgroups are arrayed in order of most limiting to least limiting. For example, within any great group the Lithic subgroup always keys first. The significant limitation posed by shallow depth to hard bedrock is considered the most limiting of all subgroups to land use and management.

Subgroup names are applied in the following order:

Lithic
Petrogypsic
Petrocalcic
Anhydritic
Gypsic
Leptic

Calcic
Salidic
Sodic

If none of the listed subgroups apply, the subgroup is considered *typic* or typical for the central concept of the great group.

Many soil taxa have properties that encompass more than one subgroup. If more than one subgroup is needed, additional names are added. To date, only two subgroups modifiers have been recognized for individual great groups identified in the United Arab Emirates. The most limiting subgroup is used to initially modify the great group and additional names are added in order of significance. For example, a pedon classified in a Torripsamment great group has properties of a lithic and salidic subgroup. The pedon would be classified at the subgroup level as a "Salidic Lithic Torripsamment". Currently, it is recommended to identify more than two subgroups as differentiae at the series level and the classification remain unchanged.

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Multicolored soil profile indicates phases of soil development

Uniform looking desert landscapes present indepth picturesque features

Horizons, Layers, and Characteristics Diagnostic for the Higher Categories

3

Abstract

This chapter defines the horizons, layers, and characteristics of mineral soils found in the UAE. Soil profiles are described according to the different soil layers that may be identified within each profile. In this chapter “required characteristics” for horizons or features, are arranged as a key. Each major layer, or master horizon, is allocated one or more letter codes, each of which has a specific meaning. The uppercase letters O, L, A, E, B, C, R, M, and W are used within the USDA-NRCS system to represent the master horizons and layers of soils. These letters are the base symbols to which other characteristics are added to complete the designations. Lowercase letters are used as suffixes to designate specific kinds of master horizons and layers. The letters aa, b, c, d, g, k, m, n, p, q, r, w, y, yy, and z are the suffix symbols used for the UAE soils. The use of prime symbol, where appropriate, is placed after the capital-letter horizon B′k and the “caret” symbol (^), for example ^A_^C-Ak, are described. Diagnostic surface (Ochric) and subsurface horizons (Anhydritic, Calcic, Cambic, Gypsic, Petrocalcic, Petrogypsic, Salic), as well as moisture (Aquic, Aridic or Torric) and a temperature regime (Hyperthermic) identified in the UAE are described. The Anhydritic horizon is a new subsurface diagnostic horizon first recognized and defined in the UAE.

Keywords

Aridic • Diagnostic horizons • Suffix letters • Moisture regime • Temperature regime

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3.1 Introduction

This chapter defines the horizons, layers, and characteristics of mineral soils found in the United Arab Emirates. The horizons and characteristics defined below are not in a key format. The "required characteristics" for horizons or features, however, are arranged as a key. Some diagnostic horizons are mutually exclusive, and some are not.

3.2 Master Horizons and Layers

Soil profiles are described according to the different soil layers that may be identified within each profile. Each major layer, or master horizon, is allocated one or more letter codes, each of which has a specific meaning. The capital letters O, L, A, E, B, C, R, M, and W are used within the USDA-NRCS system (Soil Survey Staff 2010) to represent the master horizons and layers of soils. These letters are the base symbols to which other characteristics are added to complete the designations.

Common master horizons used for soils in arid regions are:

A horizons—mineral horizons that show an accumulation of humified organic matter or show signs of cultivation;

B horizons—mineral horizons that show evidence of illuvial concentration of silicate clay, gypsum, carbonates, iron, aluminum, humus, silica, or sesquioxides alone or in combination or have structure other than rock structure;

C horizons or layers—lack the properties of O, A, E, or B horizons and may be little affected by pedogenic processes;

R layers—strongly cemented to indurated bedrock. Granite, basalt, limestone, and sandstone are examples of bedrock designated by the letter R.

Within the UAE, the conditions are generally unsuitable for the occurrence of many pedogenic processes, and thus recognition of A, B, and C horizons can be difficult. B horizons are typically identified in the UAE through the accumulation of gypsum and/or carbonates, while C horizons typically lack this development. Due to the lack of significant amounts of organic matter, the surface layers are generally defined as A horizons. However, within the dune areas, the surface layer has been blown in from elsewhere and is typically the most recent material. In general, these deep sands lack any significant profile development, and thus most of the horizons (including the surface) have been described as C horizons. Lithified layers and bedrock are encountered and are designated as R layers.

3.3 Suffix Symbols

Lowercase letters are used as suffixes to designate specific kinds of master horizons and layers. The term "accumulation" is used in many of the definitions of such horizons to indicate that these horizons must contain more of the material in question than is presumed to have been present in the parent material.

The letters aa, b, c, d, g, k, m, n, p, q, r, w, y, yy, and z are the suffix symbols used for the UAE soils. These suffixes and their meanings are described below:

aa Accumulation of anhydrite†

This symbol is used in mineral soils to indicate an accumulation of anhydrite ($CaSO_4$). Colors associated with horizons that have suffix aa typically have hue of 5Y with chroma (dry and moist) of 1 or 2, and value of 7 or 8. Soil materials containing anhydrite have a fluid manner of failure. The symbol is commonly used in combination with suffix z as "Bzaa".

b Buried genetic horizon

This symbol indicates identifiable buried horizons with major genetic features (diagonostic horizons) that were developed before burial. Genetic horizons may or may not have formed in the overlying material, which may be either like or unlike the assumed parent material of the buried soil.

c Concretions or nodules

This symbol indicates a significant accumulation of concretions or nodules. Cementation is required. The cementing agent commonly is iron, aluminum, or manganese. It cannot be silica, dolomite, calcite, or more soluble salts.

d Physical root restriction

This symbol indicates noncemented, root-restricting layers in naturally occurring or human-made sediments or materials. Examples are dense basal till, plowpans, and other mechanically compacted zones.

g Strong gleying

This symbol indicates either that iron has been reduced and removed during soil formation or that saturation with stagnant water has preserved it in a reduced state. Most of the affected layers have chroma of 2 or less, and many have redox concentrations. The low chroma can represent either the color of reduced iron or the color of uncoated sand and silt particles from which iron has been removed.

k Presence of calcium carbonates

This symbol indicates the presence of calcium carbonate as exhibited by effervescence or as visible accumulations that occur as carbonate filaments, coatings, masses, nodules, disseminated carbonate, or other forms. It was used with horizons that were very slightly to strongly effervescent (formation of bubbles) with application of dilute hydrochloric acid.

m Cementation or induration

This symbol indicates continuous or nearly continuous cementation. It is used only for horizons that are more than 90 % cemented, although they may be fractured. The cemented layer is physically root restrictive. The predominant cementing agent (or the two dominant ones) may be indicated by adding defined letter suffixes, singly or in pairs. The horizon suffix km indicates cementation by carbonates; qm, cementation by silica; yym, cementation by gypsum; kqm, cementation by carbonates and silica; and zm, cementation by salts more soluble than gypsum.

n Accumulation of sodium

This symbol indicates an accumulation of exchangeable sodium. It is used with horizons that have an exchangeable sodium percentage (ESP) of 15 or more or sodium adsorption ratio (SAR) of 13 (mmoles $L^{-1})^{0.5}$ or more.

p Tillage or other disturbance

This symbol indicates a disturbance of the surface layer by mechanical means, pasturing, or similar uses.

q Accumulation of silica

This symbol indicates an accumulation of secondary silica.

r Weathered or soft bedrock

This symbol is used with C to indicate layers of bedrock that are moderately cemented or less cemented. Examples are weathered igneous rock and partly consolidated sandstone, siltstone, or shale. The excavation difficulty is low to high.

w Development of color or structure

This symbol is used only with B horizons to indicate the development of color or structure, or both, with little or no apparent illuvial accumulation of material. It was not used to indicate a transitional horizon.

y Accumulation of gypsum

This symbol indicates an accumulation of gypsum. It was used when the horizon fabric was dominated by soil particles or minerals other than gypsum. Gypsum is present in amounts that do not significantly obscure or disrupt other features of the horizon (generally, 1–50 % or more by volume; or 5–40 % percent or more by weight).

yy Dominance of horizon by gypsum

This symbol indicates a horizon that is dominated by the presence of gypsum. The gypsum content may be due to an accumulation of secondary gypsum, the transformation of primary gypsum inherited from parent material, or other processes. Suffix yy is used when the horizon fabric has an abundance of gypsum (generally, 50 % or more, by volume; or 40 % or more, by weight) and pedogenic or lithologic features are obscured or disrupted by growth of gypsum crystals. Colors associated with horizons that have suffix yy typically are highly whitened, with value of 7 through 9.5 and chroma of 2 or less.

z Accumulation of salts more soluble than gypsum

This symbol indicates an accumulation of salts that are more soluble than gypsum. The suffix z is commonly used when the ECe is more than 4 dS/m (slightly or more saline).

3.4 Conventions for Using Letter Suffixes

Many master horizons and layers that are symbolized by a single capital letter have one or more lowercase letter suffixes. The following rules apply:

1. Letter suffixes should directly follow the capital letter.
2. More than three suffixes are rarely used.
3. If more than one suffix is needed, the following letters, if used, are written first: d, k, r, t, and w. None of these letters are used in combination in a single horizon.
4. If more than one suffix is needed and the horizon is not buried, the following symbols, if used, are written last: aa, c, g, and m (e.g., Bkm or Bzaa).
5. If a horizon is buried, the suffix b is written last (e.g., Bkb).
6. If the above rules do not apply to certain suffixes, such as k, q, or y, the suffixes may be listed together in order of assumed dominance or they are listed alphabetically if dominance is not a concern.

A B horizon that is gleyed or has accumulations of carbonates, sodium, silica, gypsum, or salts more soluble than gypsum or residual accumulations of sesquioxides carries the appropriate symbol: g, k, n, q, y, or z.

3.5 Vertical Subdivision

Commonly, a horizon or layer identified by a single letter or a combination of letters has to be subdivided. For this purpose, Arabic numerals are added to the letters of the horizon designation. These numerals follow all the letters. Within a C horizon, for example, successive layers may be designated C1, C2, C3, etc. If the lower part is gleyed and the upper part is not gleyed, the layers may be designated C1-C2-Cg1-Cg2.

These conventions apply whatever the purpose of the subdivision. In many soils a horizon that could be identified by a single set of letters is subdivided because of the need to recognize differences in morphological features, such as structure, color, or texture. These divisions are numbered consecutively with numerals, but the numbering starts again with 1 wherever in the profile any letter of the horizon symbol changes, e.g., Bk1-Bk2-Bky1-Bky2 (not Bk1-Bk2-Bky3-Bky4). The numbering of vertical subdivisions within consecutive horizons is not interrupted at a discontinuity (indicated by a numerical prefix) if the same letter combination is used in both materials, e.g., Bk1-Bk2-2Bk3-2Bk4 (not Bk1-Bk2-2Bk1-2Bk2).

During sampling for laboratory analyses, thick soil horizons are sometimes subdivided even though differences in morphology are not evident in the field. These subdivisions are identified by numerals that follow the respective horizon designations. For example, four layers of a Bk horizon sampled by 10-cm increments are designated Bk1, Bk2, Bk3, and Bk4. If the horizon has already been subdivided because of differences in morphological features, the set of numerals that identifies the additional sampling subdivisions follows the first numeral. For example, three layers of a Bk2 horizon sampled by 10-cm increments are designated Bk21, Bk22, and Bk23. The descriptions for each of these sampling subdivisions can be the same, and a statement indicating that the horizon has been subdivided only for sampling purposes can be added.

3.6 Discontinuities

Numerals are used as prefixes to horizon designations (preceding the letters A, B, C, and R) to indicate discontinuities in mineral soils. These prefixes are distinct from the numerals that are used as suffixes denoting vertical subdivisions. A discontinuity that can be identified by a number prefix is a significant change in particle-size distribution or mineralogy that indicates a difference in the material from which the horizons have formed and/or a significant difference in age, *unless that difference in age is indicated by the suffix b*.

Symbols that identify discontinuities are used only when they can contribute substantially to an understanding of the relationships among horizons. The stratification common to soils that formed in alluvium is not designated as a discontinuity, unless particle-size distribution differs markedly from layer to layer (i.e., particle-size classes are strongly contrasting), even though genetic horizons may have formed in the contrasting layers.

Where a soil has formed entirely in one kind of material, the whole profile is understood to be material 1 and the number prefix is omitted from the symbol. Similarly, the uppermost material in a profile consisting of two or more contrasting materials is understood to be material 1, but the number is omitted. Numbering starts with the second layer of contrasting material, which is designated 2. Underlying contrasting layers are numbered consecutively. Even when the material of a layer below material 2 is similar to material 1, it is designated 3 in the sequence; the numbers indicate a change in materials, not types of material. Where two or more consecutive horizons have formed in the same kind of material, the same prefix number is applied to all the designations of horizons in that material: A-Bk1-2Bk2-2Bk3-2Ck. The suffix numbers designating vertical subdivisions of the Bk horizon continue in consecutive order across the discontinuity.

However, vertical subdivisions do not continue across lithologic discontinuities if the horizons are not consecutive or contiguous to each other. If other horizons intervene, another vertical numbering sequence begins for the lower horizons: A-C1-C2-2Bk1-2Bk2-2Ck1-2Ck2. If an R layer is present below a soil that has formed in residuum and if the material of the R layer is judged to be like the material from which the soil has developed, the Arabic number prefix is not used. The prefix is used, however, if it is thought that the R layer would produce material unlike that in the solum, e.g., A-Bk-Ck-2R or A-Bk-2R. If part of the solum has formed in residuum, the symbol R is given the appropriate prefix: A-Bk1-2Bk2-2Bk3-2Ck1-2Ck2-2R.

A buried horizon (designated by the letter b) presents special problems. It is obviously not in the same deposit as the overlying horizons. Some buried horizons, however, have formed in material that is lithologically like the overlying deposit. A prefix is not used to distinguish material of such a buried horizon. If the material in which a horizon of a buried soil has formed is lithologically unlike the overlying material, however, the discontinuity is indicated by a number prefix and the symbol for the buried horizon also is used, e.g., A-Bk1-Bk2-C-2Ab-2Bkb1-2Bkb2-2C.

3.7 Use of the Prime Symbol

If two or more horizons with *identical* numeral prefixes and letter combinations are separated by one or more horizons with a different horizon designation in a pedon, identical letter and number symbols can be used for those horizons that have the same characteristics. For example, the sequence A-Bk-Bkn-Bk-CK identifies a soil that has two Bk horizons. To emphasize this characteristic, the prime symbol (′) is added after the master-horizon symbol of the lower of the two horizons that have identical designations, e.g., A-Bk-Bkn-B′k-Ck. The prime symbol, where appropriate, is placed after the capital-letter horizon designation and before the lowercase suffix letter symbols that follow it: B′k.

The prime symbol is not used unless all letters and numeral prefixes are completely identical. The sequence A-Bk1-Bk2-2Bk1-2Bk2 is an example. It has two Bk master horizons of different lithologies; thus, the Bk horizons are not identical and the prime symbol is not needed. The prime symbol is used for soils with lithologic discontinuities when horizons have identical designations. In the rare cases where three layers have identical letter symbols, double prime symbols can be used for the lowest of these horizons: Bk″.

Vertical subdivisions of horizons or layers (numeral suffixes) are not taken into account when the prime symbol is assigned. The sequence A-Bk-Bkn-B′k1-B′k2-B′k3-C is an example.

3.8 Use of the Caret Symbol

The "caret" symbol (^) is used as a prefix to master horizon designations to indicate layers of human-transported material. This material has been moved horizontally onto a pedon from a source area outside of that pedon by directed human activity, usually with the aid of machinery.

All horizons and layers formed in human-transported material are indicated by a "caret" prefix (e.g., ^A-^C-Ak-Bkb). When they can contribute substantially to an understanding of the relationship of the horizons or layers, numeral prefixes may be used before the caret symbol to indicate the presence of discontinuities within the human-transported material or between the human-transported material and underlying layers (e.g., ^A-^C-2^C-3Bkb).

3.9 Diagnostic Surface Horizons

3.9.1 The Epipedon

The epipedon (Gr. *epi*, over, upon, and *pedon*, soil) is a horizon that forms at or near the surface and in which most of the rock structure has been destroyed. It is darkened by organic matter or shows evidence of eluviation, or both. *Rock structure* as used here and in other places in this taxonomy includes fine stratification (5 mm or less thick) in unconsolidated sediments (eolian, alluvial, or marine) and saprolite derived from consolidated rocks in which the unweathered minerals and pseudomorphs of weathered minerals retain their relative positions to each other.

Any horizon may be at the surface of a truncated soil. These horizons can be covered by a surface mantle of new soil material. If the surface mantle has rock structure, the top of the epipedon is considered the soil surface unless the mantle meets the definition of buried soils. If the soil includes a buried soil, the epipedon, if any, is at the soil surface and the epipedon of the buried soil is considered a buried epipedon and is not considered in selecting taxa unless the keys specifically indicate buried horizons. A soil with a mantle thick enough to have a buried soil has no epipedon if the soil has rock structure to the surface or has an A horizon less than 25 cm thick that is underlain by soil material with rock structure.

A recent alluvial or eolian deposit that retains fine stratifications (5 mm or less thick) or an A horizon directly underlain by such stratified material is not included in the concept of the epipedon because time has not been sufficient for soil-forming processes to erase these transient marks of deposition and for diagnostic and accessory properties to develop. An epipedon is not the same as an A horizon.

3.9.1.1 Ochric Epipedon

The ochric epipedon is the only diagnostic surface horizon recognized in the UAE. It fails to meet any of the definitions for the other epipedons identified in the USDA *Keys to Soil Taxonomy* because it is too thin or too dry, has too high a color value or chroma, contains too little organic carbon, has too high an n value or melanic index, or is both massive and hard or harder when dry. The ochric epipedon does not have rock structure and does not include finely stratified fresh sediments, nor can it be an Ap horizon directly overlying such deposits.

3.10 Diagnostic Subsurface Horizons

The horizons described in this section form below the surface of the soil. They may be exposed at the surface by truncation of the soil. Some of these horizons are generally regarded as B horizons, some are considered B horizons by many but not all pedologists, and others are generally regarded as parts of the A horizon. The following diagnostic subsurface horizons have been identified in the UAE.

3.10.1 Anhydritic Horizon†

The anhydritic diagnostic horizon (Abdelfattah and Shahid 2007; Abdelfattah et al. 2008, 2009; Shahid 2010; Shahid and Abdelfattah 2008, 2009; Shahid et al. 2004, 2007, 2009, 2010; Wilson et al. 2013) is in the final stage of approval to be incorporated as part of USDA Soil Taxonomy. The criteria are as follows:

The anhydritic horizon is an illuvial horizon in which secondary anhydrite has accumulated to a significant extent.

Fig. 3.1 Well developed anhydritic horizon

Required Characteristics
An anhydritic horizon has *all* of the following properties:

1. A thickness of 15 cm or more; *and*
2. 5 % or more (by weight) anhydrite; *and*
3. Has hue of 5Y with chroma (dry and moist) of 1 or 2, and value of 7 or 8; *and*
4. A product of thickness, in cm, multiplied by the anhydrite content (percent by weight) of 150 or more. Thus, a horizon 30 cm thick that is 5 % anhydrite qualifies as an anhydritic horizon, *and*
5. Anhydrite should be the predominant mineral, with gypsum either absent or occurring only in minor amounts (Fig. 3.1).

3.10.2 Calcic Horizon

The calcic horizon is an illuvial horizon in which secondary calcium carbonate or other carbonates have accumulated to a significant extent.

Required Characteristics
The calcic horizon:

1. Is 15 cm or more thick; *and*
2. Has *one or more* of the following:
   or
   (a) 15 % or more (by weight) $CaCO_3$ equivalent and 5% or more (by volume) identifiable secondary carbonates; *or*
   (b) 5 % or more (by weight) calcium carbonate equivalent and:
   (1) Has less than 18 % clay in the fine-earth fraction; *and*
   (2) Meets the criteria for a sandy, sandy-skeletal, coarse-loamy, or loamy-skeletal particle-size class; *and*
3. Is not cemented or indurated in any part by carbonates, with or without other cementing agents, or is cemented in some part and the cemented part satisfies *one* of the following:
   (a) It is characterized by so much lateral discontinuity that roots can penetrate through noncemented zones or along vertical fractures with a horizontal spacing of less than 10 cm; *or*
   (b) The cemented layer is less than 1 cm thick and consists of a laminar cap underlain by a lithic or paralithic contact; *or*
   (c) The cemented layer is less than 10 cm thick.

3.10.3 Cambic Horizon

A cambic horizon is the result of physical alterations, chemical transformations, or removals or of a combination of two or more of these processes.

Required Characteristics
The cambic horizon is an altered horizon 15 cm or more thick. In addition, the cambic horizon must meet all of the following:

1. Has a texture class of very fine sand, loamy very fine sand, or finer; *and*
2. Shows evidence of alteration in the following forms:
   (a) Has soil structure, *or*
   (b) The absence of rock structure, including fine stratifications (5 mm or less thick), in more than one-half of the volume and one or more of the following properties:
      (1) Higher chroma, higher value, redder hue, or higher clay content than the underlying horizon or an overlying horizon; *or*

    (2) Evidence of the removal of carbonates or gypsum; *and*
3. Has properties that do not meet the requirements for a calcic, gypsic, petrocalcic, or petrogypsic; *and*
4. Is not part of an Ap horizon.

3.10.4 Gypsic Horizon

The gypsic horizon is a horizon in which gypsum has accumulated or been transformed to a significant extent. It typically occurs as a subsurface horizon, but it may occur at the surface in some soils.

Required Characteristics
A gypsic horizon meets all of the following requirements:

1. Is 15 cm or more thick; *and*
2. Is not cemented by gypsum, with or without other cementing agents; is cemented and the cemented parts are less than 5 mm thick; or is cemented but, because of lateral discontinuity, roots can penetrate along vertical fractures with a horizontal spacing of less than 10 cm; *and*
3. Is 5 % or more (by weight) gypsum and has 1 % or more (by volume) visible secondary gypsum that has either accumulated or been transformed; *and*
4. Has a product of thickness, in cm, multiplied by the gypsum content (percent by weight) of 150 or more. Thus, a horizon 30 cm thick that is 5 % gypsum qualifies as a gypsic horizon if it is 1 % or more (by volume) visible gypsum and any cementation is as described in 2 above (Fig. 3.2).

3.10.5 Petrocalcic Horizon

The petrocalcic horizon is an illuvial horizon in which secondary calcium carbonate or other carbonates have accumulated to the extent that the horizon is cemented or indurated.

Required Characteristics
A petrocalcic horizon must meet the following requirements:

1. The horizon is cemented or indurated by carbonates, with or without silica or other cementing agents; *and*

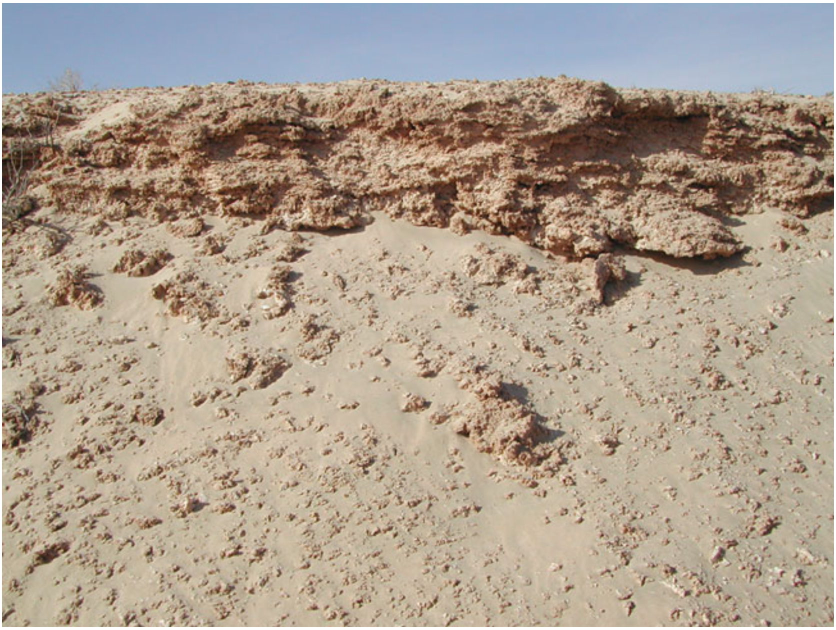

Fig. 3.2 Example of gypsic horizon

2. Because of lateral continuity, roots can penetrate only along vertical fractures with a horizontal spacing of 10 cm or more; *and*
3. The horizon has a thickness of:
   (a) 10 cm or more; *or*
   (b) 1 cm or more if it consists of a laminar cap directly underlain by bedrock (Fig. 3.3).

3.10.6 Petrogypsic Horizon

The petrogypsic horizon is a horizon in which visible secondary gypsum has accumulated or has been transformed. The horizon is cemented (i.e., extremely weakly through indurated cementation classes), and the cementation is both laterally continuous and root limiting, even when the soil is moist. The horizon typically occurs as a subsurface horizon, but it may occur at the surface in some soils.

Fig. 3.3 Example of petrocalcic horizon

Required Characteristics
A petrogypsic horizon meets *all* of the following requirements:

1. Is cemented or indurated by gypsum, with or without other cementing agents (Fig. 3.4); *and*
2. Because of lateral continuity, can be penetrated by roots only along vertical fractures with a horizontal spacing of 10 cm or more; *and*
3. Is 5 mm or more thick; *and*
4. Is 40 % or more (by weight) gypsum.

3.10.7 Salic Horizon

A salic horizon is a horizon of accumulation of salts that are more soluble than gypsum in cold water.

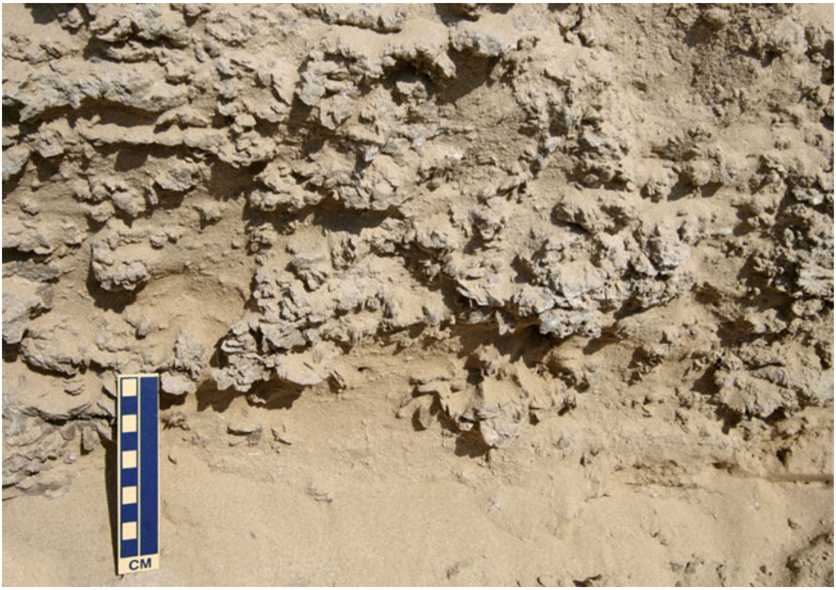

Fig. 3.4 Example of strongly cemented petrogypsic horizon

Required Characteristics
A salic horizon is 15 cm or more thick and has, for 90 consecutive days or more in normal years:

1. An electrical conductivity (EC) equal to or greater than 30 dS/m in the water extracted from a saturated paste; *and*
2. A product of the EC, in dS m^{-1}, and thickness, in cm, equal to 900 or more.

3.11 Horizons and Characteristics-Diagnostics for Mineral Soils

Following are descriptions of the horizons and characteristics that are diagnostic for mineral soils of the Unites Arab Emirates.

3.11.1 Aquic Conditions

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

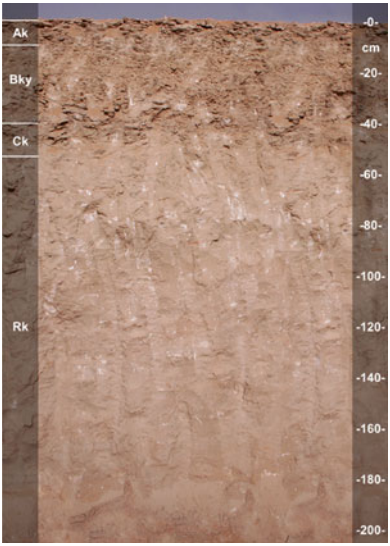

Fig. 3.5 Profile showing lithic contact at 45 cm depth (AD113)

3.11.2 Lithic Contact

A lithic contact is the boundary between soil and a coherent underlying material (Fig. 3.5). The underlying material must be virtually continuous within the limits of a pedon. Cracks that can be penetrated by roots are few, and their horizontal spacing is 10 cm or more. The underlying material must be sufficiently coherent when moist to make hand-digging with a spade impractical, although the material may be chipped or scraped with a spade. The material below a lithic contact must be in a strongly cemented or more cemented rupture-resistance class. Commonly, the material is indurated. The underlying material considered here does not include diagnostic soil horizons, such as a duripan or a petrocalcic horizon. A lithic contact is diagnostic at the subgroup level if it is within 50 cm of the surface for the soils which occur in the UAE.

3.11.3 Paralithic Contact

A paralithic (lithic-like) contact is a contact between soil and paralithic materials (defined below) where the paralithic materials have no cracks or the spacing of cracks that roots can enter is 10 cm or more.

3.11.4 Paralithic Materials

Paralithic materials are relatively unaltered materials (do not meet the requirements for any other named diagnostic horizons or any other diagnostic soil characteristic) that have an extremely weakly cemented to moderately cemented rupture-resistance class. Cementation, bulk density, and the organization are such that roots cannot enter, except in cracks. Paralithic materials have, at their upper boundary, a paralithic contact if they have no cracks or if the spacing of cracks that roots can enter is 10 cm or more. Commonly, these materials are partially weathered bedrock or weakly consolidated bedrock, such as sandstone, siltstone, or shale. Paralithic materials can be used to differentiate soil series if the materials are within the series control section. Fragments of paralithic materials 2.0 mm or more in diameter are referred to as pararock fragments.

3.11.5 Soil Moisture Regimes

The term “soil moisture regime” refers to the presence or absence either of ground water or of water held at a tension of less than 1,500 kPa in the soil or in specific horizons during periods of the year. Water held at a tension of 1,500 kPa or more is not available to keep most mesophytic plants alive. The availability of water is also affected by dissolved salts. If a soil is saturated with water that is too salty to be available to most plants, it is considered salty rather than dry. Consequently, a horizon is considered dry when the moisture tension is 1,500 kPa or more and is considered moist if water is held at a tension of less than 1,500 kPa but more than zero. A soil may be continuously moist in some or all horizons either throughout the year or for some part of the year. It may be either moist in winter and dry in summer or the reverse. In the Northern Hemisphere, summer refers to June, July, and August and winter refers to December, January, and February.

Normal Years
A normal year is defined as a year that has:

1. Annual precipitation that is plus or minus one standard deviation of the long-term (30 years or more) mean annual precipitation; *and*
2. Mean monthly precipitation that is plus or minus one standard deviation of the long-term monthly precipitation for 8 of the 12 months.

For the most part, normal years can be calculated from the mean annual precipitation; however, when catastrophic events occur during a year, the standard deviations of the monthly means should also be calculated. The term “normal years” replaces the terms “most years” and “6 out of 10 years,” which were used in the 1975 edition of *Soil Taxonomy* (USDA, SCS 1975). When precipitation data are evaluated to determine if the criterion for the presence of aquic conditions, or number of days that the moisture control section is moist, or number of days that some part of the soil is saturated has been met, it is permissible to include data from periods with below normal rainfall. Similarly, when precipitation data are evaluated to determine if the criterion for the number of days that the moisture control section is dry has been met, it is permissible to include data from periods with above normal rainfall. It is assumed that if the criteria are met during these periods, they will also be met during normal years.

3.11.5.1 Classes of Soil Moisture Regimes

The soil moisture regimes are defined in terms of the level of ground water and in terms of the seasonal presence or absence of water held at a tension of less than 1,500 kPa in the moisture control section. It is assumed in the definitions that the soil supports whatever vegetation it is capable of supporting, i.e., crops, grass, or native vegetation, and that the amount of stored moisture is not being increased by irrigation or fallowing. These cultural practices affect the soil moisture conditions as long as they are continued.

Aquic soil moisture regime.—The aquic (L. *aqua*, water) soil moisture regime is a reducing regime in a soil that is virtually free of dissolved oxygen because it is saturated by water (Fig. 3.6). Some soils are saturated with water at times while dissolved oxygen is present, either because the water is moving or because the environment is unfavorable for micro-organisms (e.g., if the temperature is less than 1°C); such a regime is not considered aquic.

It is not known how long a soil must be saturated before it is said to have an aquic soil moisture regime, but the duration must be at least a few days, because it is implicit in the concept

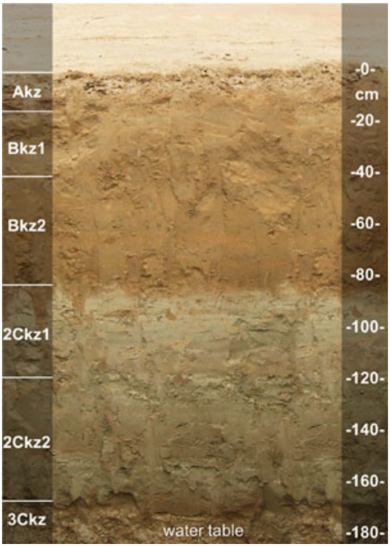

Fig. 3.6 Profile showing aquic moisture regime (AD147)

that dissolved oxygen is virtually absent. Because dissolved oxygen is removed from ground water by respiration of microorganisms, roots, and soil fauna, it is also implicit in the concept that the soil temperature is above biologic zero for some time while the soil is saturated. Biologic zero is defined as 5°C in this taxonomy.

Aridic and torric (L. *aridus*, dry, and L. *torridus*, hot and dry) soil moisture regimes.—These terms are used for the same moisture regime but in different categories of the taxonomy. In the aridic (torric) soil moisture regime, the moisture control section is, in normal years:

1. Dry in all parts for more than half of the cumulative days per year when the soil temperature at a depth of 50 cm below the soil surface is above 5°C; *and*
2. Moist in some or all parts for less than 90 consecutive days when the soil temperature at a depth of 50 cm below the soil surface is above 8°C.

Soils that have an aridic (torric) soil moisture regime normally occur in areas of arid climates. A few are in areas of semiarid climates and either have physical properties that keep them dry, such as a crusty surface that virtually precludes the infiltration of water, or are on steep slopes where runoff is high. There is little or no leaching in this soil moisture regime, and soluble salts accumulate in the soils if there is a source.

3.11.6 Soil Temperature Regime

Following is a description of the soil temperature regime identified in the UAE and used in defining the hyperthermic soil temperature class which is used at the family categorical level of soil taxonomy.

Hyperthermic.—The mean annual soil temperature is 22°C or higher, and the difference between mean summer and mean winter soil temperatures is 6°C or more either at a depth of 50 cm below the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower.

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Field kit used to establish soil taxa

Greening the desert to combat desertification in UAE

Family and Series Differentiae

4

Abstract

This chapter describes families and series identified in the UAE. The families and series are established using various criteria for mineral soils. The particle-size classes and their substitutes, mineralogy classes, cation-exchange activity classes, soil temperature classes, soil depth classes of the control section of soil taxa are used. Particle-size classes (Fragmental, Gypseous-skeletal, Coarse-gypseous, Fine gypseous, Sandy-skeletal, Loamy-skeletal, Sandy, loamy, Coarse-loamy, Fine-loamy, Coarse-silty, Fine-silty, fine), Mineralogy classes (hypergypsic, anhydritic, gypsic, carbonatic and mixed), Cation-exchange activity classes (superactive, active, semiactive, subactive), Soil temperature class (hyperthermic) and Soil depth class (shallow), Key to phases of soil classes (lithic, salic, petrogypsic, petrocalcic, anhydritic, gypsic, calcic, salidic, sodic, aquic, shelly) identified in the UAE are described.

Keywords

Soil family • Particle size classes • Mineralogy classes • Cation exchange activity • Soil depth classes

4.1 Introduction

The following differentiae are used to distinguish families of mineral soils. The class names of these components are used to form the family name. The components are listed and defined in the same sequence in which the components appear in the family names. When written, family classes are separated by a comma (Typic Torripsamments, carbonatic, hyperthermic, *salic*). It should be noted that not all families are provided in the name for each subgroup. For example, since

S.A. Shahid et al., *United Arab Emirates Keys to Soil Taxonomy*,
DOI 10.1007/978-94-007-7420-9_4,

Torripsamments (by definition) are sandy, it would be redundant to list the particle size class in the family name. If more than one phase is needed, they are separated by a hyphen (Typic Torripsamments, carbonatic, hyperthermic, lithic-salidic).

Particle-size classes and their substitutes
Mineralogy classes
Cation-exchange activity classes
Calcareous and reaction classes
Soil temperature classes
Soil depth classes
Phases of soil taxa

4.2 Definition of Particle-Size Classes

The term particle-size class is used to characterize the grain-size composition of the whole soil, including both the fine earth and the rock and pararock fragments up to the size of a pedon, but it excludes organic matter and salts more soluble than gypsum. The particle-size (texture) classes are based on percentages, by weight, in the fraction less than 2.0 mm in diameter.

4.2.1 Control Section for Particle-Size Classes

The particle-size and substitute class names listed below are applied to certain horizons, or to the soil materials within specific depth limits, that have been designated as the control section for particle-size classes and their substitutes. The lower boundary of the control section may be at a specified depth (in centimeters) below the mineral soil surface, or it may coincide with the upper boundary of a root-limiting layer (defined below).

4.2.1.1 Root-Limiting Layers

Unless otherwise indicated, the following are considered root-limiting layers in the UAE: a petrocalcic horizon, a petrogypsic horizon, a lithic contact, or a paralithic contact.

4.2.1.2 Key to the Control Section for Particle-Size Classes

The following list of particle-size control sections for the soils of the UAE is arranged as a key to allow the reader to make the correct classification by starting at the beginning and eliminating one by one all classes that include criteria that do not fit the soil in question. The soil belongs to the first class for which it meets all of the criteria listed.

(A) For mineral soils that have a root-limiting layer (listed above) within 36 cm of the mineral soil surface, from the mineral soil surface to the root-limiting layer; *or*

(B) Between the lower boundary of an Ap horizon or surface layer or a depth of 25 cm below the mineral soil surface, whichever is deeper, and the shallower of the following: (a) a depth of 100 cm below the mineral soil surface or (b) a root-limiting layer.

4.2.1.3 Key to the Particle-Size Classes

This key to UAE soils is arranged to allow the reader to make the correct particle-size distribution classification by going through the key systematically, starting at the beginning and eliminating one by one all classes that include criteria that do not fit the soil or layer in question. These classes have been or are expected to be identified in UAE soils.

Throughout the control section, meet one of the following sets of particle-size class criteria:

1. Mineral soils that have a fine-earth component of less than 10 % (including associated medium and finer pores) of the total volume (Fig. 4.1).
   Fragmental
   or
2. Have, in the fraction less than 20 mm in diameter, 40 % or more (by weight) gypsum *and* one of the following:
   (a) A total of 35 % or more (by volume) rock fragments.
   Gypseous-skeletal
   or
   (b) Less than 35 % (by volume) rock fragments and 50 % or more (by weight) particles with diameter of 0.1–2 mm.
   Coarse-gypseous
   or

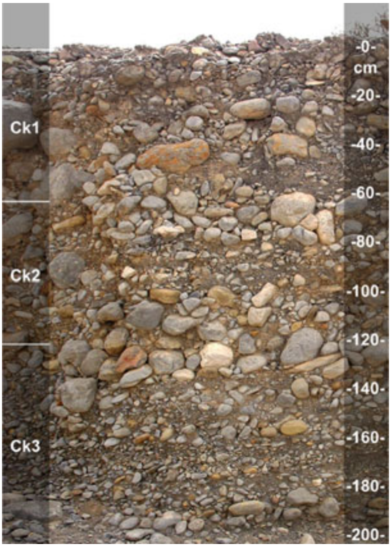

Fig. 4.1 Profile showing fragmental particle size class (NE002)

(c) Less than 35 % (by volume) rock fragments.

Fine-gypseous

or

3. Have 35 % or more (by volume) rock fragments *and* a fine-earth fraction with a texture class of sand or loamy sand, including less than 50 % (by weight) very fine sand (Fig. 4.2).

Sandy-skeletal

or

4. Have 35 % or more (by volume) rock fragments and less than 35 % (by weight) clay.

Loamy-skeletal

or

5. Have a texture class of sand or loamy sand, including less than 50 % (by weight) very fine sand particles in the fine-earth fraction (Fig. 4.3).

Sandy

or

6. Have a texture class of loamy very fine sand, very fine sand, or finer, including less than 35 % (by weight) clay in the fine-earth fraction, and are in a shallow family or in a Lithic subgroup.

Loamy

or

7. Have, in the fraction less than 75 mm in diameter, 15 % or more (by weight) particles with diameters of 0.1–75 mm (fine sand or coarser, including gravel) *and*, in the fine-earth fraction, less than 18 % (by weight) clay (Fig. 4.4).

Coarse-loamy

or

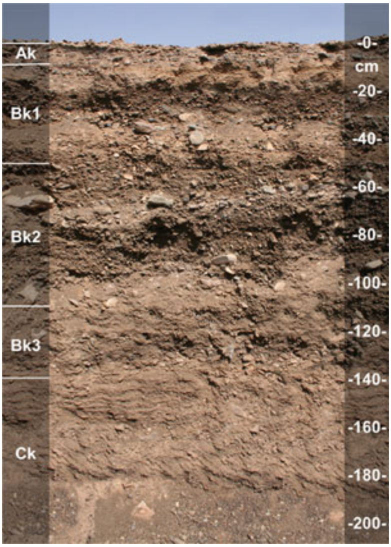

Fig. 4.2 Profile showing sandy-skeletal particle size class (AD105)

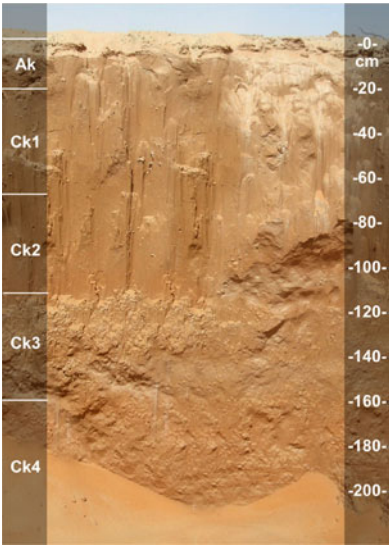

Fig. 4.3 Profile showing sandy particle size class (AD158)

8. Have, in the fraction less than 75 mm in diameter, 15 % or more (by weight) particles with diameters of 0.1–75 mm (fine sand or coarser, including gravel) *and*, in the fine-earth fraction, 18–35 % (by weight) clay.

Fine-loamy

or

9. Have, in the fraction less than 75 mm in diameter, less than 15 % (by weight) particles with diameters of 0.1–75 mm (fine sand or coarser, including gravel) *and*, in the fine-earth fraction, less than 18 % (by weight) clay (Fig. 4.5).

Coarse-silty

10. Have in the fraction less than 75 mm in diameter, less than 15 % (by weight) particles with diameters of 0.1–75 mm (fine sand or coarser, including gravel) *and*, in the fine-earth fraction, 18–35 % (by weight) clay.

Fine-silty

or

11. Have (by weighted average) less than 60 % (by weight) clay in the fine-earth fraction.

Fine

4.2.2 Strongly Contrasting Particle-Size Classes

The purpose of strongly contrasting particle-size classes is to identify changes in pore-size distribution or composition that are not identified in

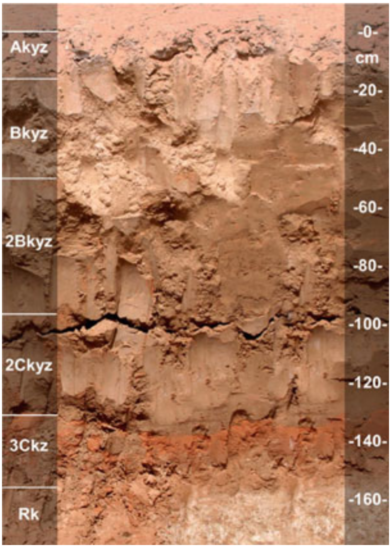

Fig. 4.4 Profile showing coarse-loamy particle size class (AD132)

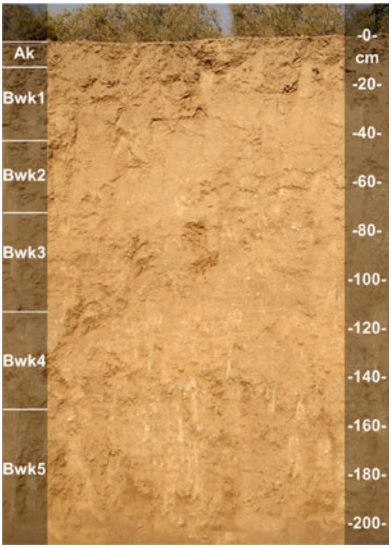

Fig. 4.5 Profile showing coarse-silty particle size class (NE019)

higher soil categories and that seriously affect the movement and retention of water and/or nutrients.

The particle-size or substitute classes listed below are considered strongly contrasting if both parts are 12.5 cm or more thick (including the thickness of these parts not entirely within the particle-size control section; however, substitute class names are used only if the soil materials to which they apply extend 10 cm or more into the upper part of the particle-size control section) and if the transition zone between the two parts of the particle-size control section is less than 12.5 cm thick.

Some classes, such as sandy and sandy-skeletal, have been combined in the following list. In those cases the combined name is used as the family class if part of the control section meets the criteria for either class.

To date three strongly contrasting particle-size classes have been identified in the United Arab Emirates. The following classes are not presented in a key format.

1. Fine-gypseous over loamy: Um Al Quwain Series
2. Coarse-loamy over sandy or sandy-skeletal (if the coarse-loamy material contains less than 50 %, by weight, fine sand or coarser sand): Wahala Series
3. Sandy over loamy: As Sihebi Series

4.3 Mineralogy Classes

The mineralogy of soils is known to be useful in making predictions about soil behavior and responses to management. Some mineralogy classes occur or are important only in certain taxa or particle-size classes, and others are important in all particle-size classes.

4.3.1 Control Section for Mineralogy Classes

The control section for mineralogy classes is the same as that defined for the particle-size classes and their substitutes.

4.3.2 Key to Mineralogy Classes

This key, like other keys in this taxonomy, is designed in such a way that the reader makes the correct classification by going through the key systematically, starting at the beginning and eliminating one by one any classes that include criteria that do not fit the soil in question. The soil belongs to the first class for which it meets all of the required criteria. The user should first check the criteria listed in the first class, if the soil in question does not meet the criteria listed there, proceed on to the next class, until the soil meets the criteria listed. All criteria are based on a weighted average.

For soils with strongly contrasting particle-size classes, mineralogy classes are used for both of the named parts of particle-size classes or substitute classes, unless they are the same. The same mineralogy class name cannot be used for both parts of the control section (e.g., "mixed over mixed"). Example of a soil that requires assignment of two different mineralogy classes is a fine-gypseous over loamy, hypergypsic over carbonatic, hyperthermic Gypsic Aquisalid.

1. Soil layers or horizons, in the mineralogy control section, that have a substitute class that replaces the particle-size class, other than fragmental, and that have 40 % or more (by weight) gypsum either in the fine-earth fraction or in the fraction less than 20 mm in size, whichever has a higher percentage of gypsum.

Hypergypsic

or

2. Soil layers or horizons that have any particle-size class and 15 % or more (by weight) anhydrite, either in the fine-earth fraction or in the fraction less than 20 mm in size, whichever has a higher percentage of anhydrite (Fig. 4.6).

Anhydritic

or

3. Soil layers or horizons, in the mineralogy control section, that have any particle-size class and 15 % or more (by weight) gypsum, either in the fine-earth fraction (less than 2 mm)

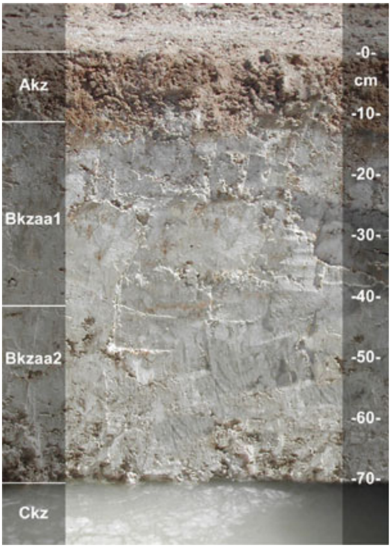

Fig. 4.6 Soil profile showing anhydritic mineralogy class (AD125)

or in the fraction less than 20 mm in size, whichever has a higher percentage of gypsum (Fig. 4.7).

Gypsic

or

4. Soil layers or horizons that have any particle-size class and more than 40 % (by weight) carbonates (expressed as $CaCO_3$) plus gypsum plus anhydrite, either in the fine-earth fraction or in the fraction less than 20 mm in size, whichever has a higher percentage of carbonates plus gypsum plus anhydrite (Fig. 4.8).

Carbonatic

or

5. Soils with mineralogy classes other than hypergypsic, anhydritic, gypsic, carbonatic, or siliceous.

Mixed

4.4 Cation-Exchange Activity Classes

The cation-exchange activity classes help in making interpretations of mineral assemblages and of the nutrient holding capacity of soils in mixed mineralogy classes of loamy-skeletal, loamy, coarse-loamy, fine-loamy, fine-silty, and fine particle-size classes.

Cation-exchange activity classes are not assigned to Psamments, “psamm” great groups of Entisols, or other soils with sandy or sandy-skeletal particle-size classes or the fragmental substitute

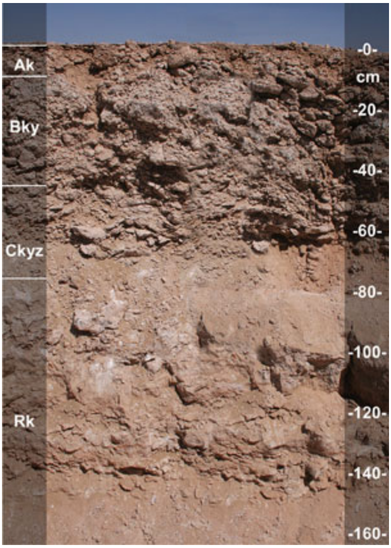

Fig. 4.7 Soil profile showing gypsic mineralogy class (AD111)

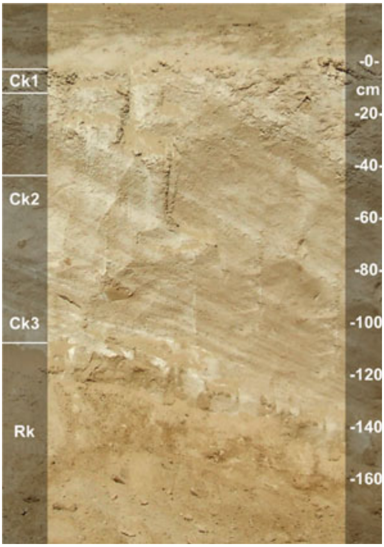

Fig. 4.8 Soil profile showing carbonatic mineralogy class (AD156)

class because the low clay content causes cation-exchange activity classes to be less useful and less reliable.

The cation-exchange capacity is determined by NH_4OAc at pH 7 on the fine-earth fraction. The CEC of the organic matter, sand, silt, and clay is included in the determination.

The criteria for the classes use ratios of CEC to the percent, by weight, of silicate clay, both by weighted average in the control section. In the following classes "clay" excludes clay-size carbonates. If the ratio of percent water retained at 1,500 kPa tension to the percentage of measured clay is 0.25 or less or 0.6 or more in half or more of the particle-size control section (or part in contrasting families), then the percentage of clay is estimated by the following formula: Clay % = 2.5(% water retained at 1,500 kPa tension—% organic carbon).

4.4.1 Control Section for Cation-Exchange Activity Classes

The control section for cation-exchange activity classes is the same as that used to determine the particle-size and mineralogy classes. For soils with strongly contrasting particle-size classes, where both named parts of the control section use a cation exchange activity class, the class associated with the particle size class that has the most clay is named.

4.4.2 Key to Cation-Exchange Activity Classes

A. Soils that are not Psamments, and that are not in a sandy or sandy-skeletal particle-size class or any substitute for a particle-size class (including fragmental), and that have:

1. A mixed mineralogy class; and
2. A ratio of cation-exchange capacity (by IN NH_4OAc pH 7) to percent clay (by weight) of:
   (a) 0.60 or more.

   Superactive

   (b) 0.40 to less than 0.60

   Active

(c) 0.24 to less than 0.40

Semiactive

(d) Less than 0.24

Subactive

4.5 Soil Temperature Classes

Soil temperature class, as named and defined here, is used as part of the family name. The Celsius (centigrade) scale is the standard. It is assumed that the temperature is that of a soil that is not being irrigated.

4.5.1 Control Section for Soil Temperature

The control section for soil temperature is either at a depth of 50 cm below the soil surface or at the upper boundary of a root-limiting layer, whichever is shallower. The soil temperature class is defined in terms of the mean annual soil temperature and the difference between mean summer and mean winter temperatures.

The only soil temperature class identified in the UAE is the **hyperthermic** class. It is defined for soils that have a difference in soil temperature of 6°C or more between mean summer (June, July, and August) and mean winter (December, January, and February) and a mean annual soil temperature of 22°C (72°F) or higher.

Hyperthermic

4.6 Soil Depth Classes

Soil depth class is used in families of United Arab Emirates mineral soils that have a root-limiting layer at a specified depth from the mineral soil surface. The root-limiting layers included in soil depth classes are petrocalcic or petrogypsic horizons and paralithic contact. Shallow soils that meet the criteria for «lithic contact» using the USDA-*Keys to Soil Taxonomy* (11th and previous editions, Soil Survey Staff 2010) have now been assigned to the appropriate “Lithic” subgroups in the *UAE Keys to Soil Taxonomy*.

4.6.1 Key to Soil Depth Classes

(A) Mineral soils that are less than 50 cm deep (from the soil surface) to a root-limiting layer (petrogypsic or petrocalcic horizon, or a paralithic contact) excluding soils that are in a Lithic subgroup (Fig. 4.9).

Shallow

(B) All other mineral soils: No soil depth class used.

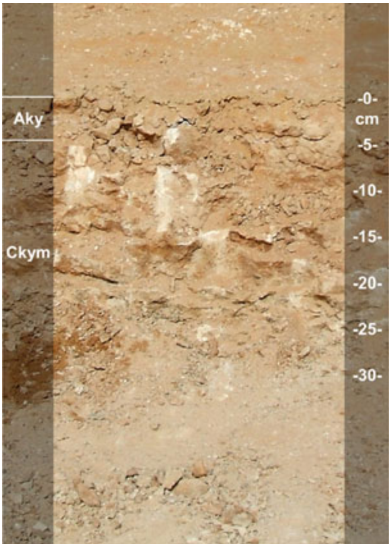

Fig. 4.9 Example showing shallow phase (AD124)

4.7 Phases of Soil Taxa

Phases of soil taxa have been developed for those mineral soils that have soil properties or characteristics that occur at a deeper depth than currently identified for an established taxonomic subgroup or soil properties that effect interpretations not currently recognized at the subgroup level. The phases which have been identified in the UAE include: anhydritic, aquic, calcic, gypsic, lithic, petrocalcic, petrogypsic, salic, salidic, shelly, and sodic.

Phases are added to the family classification separated by a comma (Typic Torripsamments, carbonatic, hyperthermic, salic). If more than one contrasting phase is needed, the phases are separated by a hyphen and listed in the same order as the Key (Typic Torripsamments, carbonatic, hyperthermic, lithic-salidic). Rarely are more than two phases used.

Phases are not repeated when the soil feature is recognized at the subgroup level even though it also occurs at a lower depth (e.g., Salidic Haplocalcids, sandy, carbonatic, hyperthermic, salidic). However, they are used if different than the subgroup name (e.g., Salidic Haplocalcids, sandy, carbonatic, hyperthermic, salic).

4.7.1 Key to Phases

(A) Mineral soils that have a lithic contact at a depth of more than 50–200 cm from the soil surface (Fig. 4.10).

Lithic

or

(B) Mineral soils that have, at a depth of more than 100–200 cm from the soil surface, one or more of the following:

1. A salic horizon.

Salic

or

2. A petrogypsic horizon.

Petrogypsic

or

3. A petrocalcic horizon.

Petrocalcic

or

4. An anhydritic horizon.

Anhydritic[1]

or

5. A gypsic horizon.

Gypsic

or

6. A calcic horizon.

Calcic

or

7. An ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick.

Salidic

or

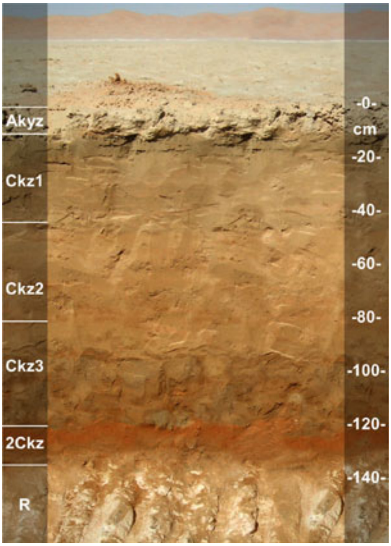

Fig. 4.10 Example showing lithic phase (AD148)

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[1] For the *Soil Survey of the Abu Dhabi Emirate—Extensive Survey*, the "anhydritic" phase represented those soils that contained large amounts of anhydrite in place of gypsum within a depth of 100 cm of the soil surface. These soils were classified in a "Gypsic" subgroup because (at the time of publication) the anhydritic subgroup had not been established. Currently, the anhydritic phase is used for those soils with an anhydritic horizon at a depth of more than 100–200 cm from the soil surface.

8. An exchangeable sodium percentage of 15 or more (or an SAR of 13 or more) during at least 1 month in normal years and an ECe of 8 dS m^{-1} or less in any layer with a thickness of 10 cm or more:

Sodic

or

9. Are saturated with water in one or more layers for 1 month or more in normal years.

Aquic

or

(C) Mineral soils that have, within a depth of 200 cm from the soil surface, a horizon 15 cm or more thick with 35 % or more (by volume) broken or unbroken sea shell fragments.

Shelly

Reference

Soil Survey Staff. (2010). *Keys to soil taxonomy* (11th ed.). Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service. U.S. Government Printing Office.

Barchan dunes (Entisols) cover large part of the UAE

Identification of the Taxonomic Class of a Soil

5

Abstract

In this chapter, key to soil taxonomy hierarchy of UAE, from order-suborder-great group-subgroups are described. Within the soil order Aridisols, the soil taxa have been described as suborders, great groups and subgroups, such as, Suborders (Salids, Gypsids, Calcids, Cambids), Great Groups (Petrocalcids, Haplocalcids, Petrogypsids, Haplocambids, Calcigypsids, Haplogypsids, Aquisalids, Haplosalids), and Subgroups (Salidic Lithic Haplocalcids, Lithic Haplocalcids, Salidic Haplocalcids, Sodic Haplocalcids, Typic Haplocalcids, Calcic Petrocalcids, Typic Petrocalcids, Sodic Haplocambids, Fluventic Haplocambids, Typic Haplocambids, Lithic Calcigypsids, Salidic Calcigypsids, Typic Calcigypsids, Salidic Lithic Haplogypsids, Lithic Haplogypsids, Salidic Leptic Haplogypsids, Leptic Haplogypsids, Salidic Haplogypsids, Typic Haplogypsids, Salidic Lithic Petrogypsids, Lithic Petrogypsids, Salidic Calcic Petrogypsids, Calcic Petrogypsids, Salidic Petrogypsids, Typic Petrogypsids, Gypsic Lithic Aquisalids, Lithic Aquisalids, Petrogypsic Aquisalids, Anhydritic Aquisalids, Gypsic Aquisalids, Typic Aquisalids, Petrogypsic Lithic Haplosalids, Gypsic Lithic Haplosalids, Calcic Lithic Haplosalids, Lithic Haplosalids, Petrogypsic Haplosalids, Anhydritic Haplosalids, Leptic Gypsic Haplosalids, Gypsic Haplosalids, Calcic Haplosalids, and Typic Haplosalids). Within the order Entisols, the soil taxa have been described as Suborders (Aquents, Psamments, Orthents), Great Groups (Psammaquents, Torriorthents, Torripsamments), Subgroups (Salidic Psammaquents, Salidic Lithic Torriorthents, Lithic Torriorthents, Salidic Torriorthents, Sodic Torriorthents, Typic Torriorthents, Salidic Lithic Torripsamments, Lithic Torripsamments, Oxyaquic Torripsamments, Salidic Torripsamments, Sodic Torripsamments, and Typic Torripsamments).

S.A. Shahid et al., *United Arab Emirates Keys to Soil Taxonomy*,
DOI 10.1007/978-94-007-7420-9_5,

Keywords
Soil order • Suborder • Great group • Sub group • Soil taxa

5.1 Introduction

In the United Arab Emirates, Aridisols and Entisols soil orders have been recognized (Soil Survey Staff 2010). Most of the natural desert landscapes are not in use (Fig. 5.1), in places agriculture has been established using smart irrigation systems (Fig. 5.2).

Fig. 5.1 Natural desert landscape with Aridisols (foreground) and Entisols (background)

5.2 Key to Soil Orders

The soils that:

1. Have:
   (a) An aridic soil moisture regime; *and*
   (b) An ochric epipedon; *and*
   (c) One or more of the following within 100 cm of the soil surface: a cambic horizon with a lower depth of 25 cm or more; an anhydritic horizon; a calcic, gypsic, petrocalcic, petrogypsic, or salic horizon; *or*
2. Have a salic horizon; *and*
   (a) Saturation with water in one or more layers within 100 cm of the soil surface for 1 month or more during a normal year; *and*

Fig. 5.2 Typical desert landscape with proper land management and irrigated agriculture

(b) A moisture control section that is dry in some or all parts at some time during normal years.

Aridisols, p. 53

or

Other soils that do not classify as Aridisols.

Entisols, p. 70

5.3 Key to the Suborders of Aridisols

Aridisols that have a salic horizon within 100 cm of the soil surface.

Salids, p. 63

Other Aridisols that have a gypsic or petrogypsic horizon within 100 cm of the soil surface and do not have a petrocalcic horizon overlying these horizons.

Gypsids, p. 57

Other Aridisols that have a calcic or petrocalcic horizon within 100 cm of the soil surface.

Calcids, p. 54

Other Aridisols that have a cambic horizon within 100 cm of the soil surface.

Cambids, p. 56

5.3.1 Calcids

Key to Great Groups
Calcids that have a petrocalcic horizon within 100 cm of the soil surface.

Petrocalcids, p. 55

Other soils that are the most extensive of the Calcids and do not have a petrocalcic horizon with its boundary within 100 cm of the soil surface.

Haplocalcids, p. 54

5.3.1.1 Haplocalcids

Key to Subgroups
Haplocalcids that have both:

1. An ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface: *and*
2. A lithic contact within 50 cm of the soil surface.

Salidic Lithic Haplocalcids

Other Haplocalcids that have a lithic contact within 50 cm of the soil surface (Fig. 5.3).

Lithic Haplocalcids

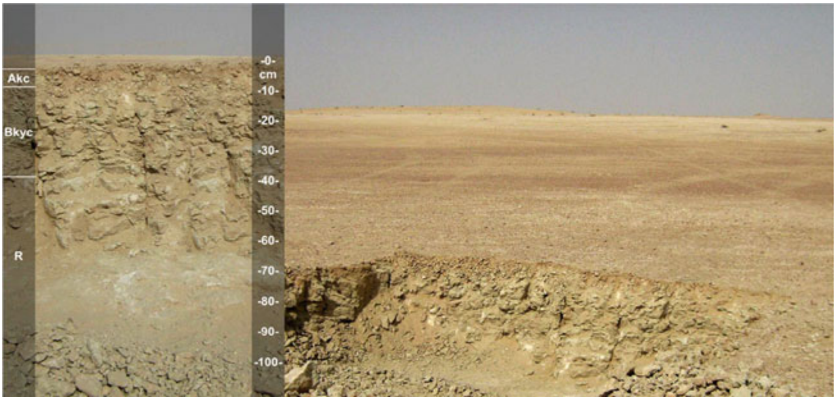


Fig. 5.3 Soilscape showing Lithic Haplocalcids (AD201)

Other Haplocalcids that have an ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface:

Salidic Haplocalcids

Other Haplocalcids that have, in a horizon at least 25 cm thick within 100 cm of the mineral soil surface, an exchangeable sodium percentage of 15 or more (or an SAR of 13 or more) during at least 1 month in normal years.

Sodic Haplocalcids

Other Haplocalcids that have a calcic horizon within 100 cm of the soil surface and lack all other characteristics of any other subsurface horizon (Fig. 5.4).

Typic Haplocalcids

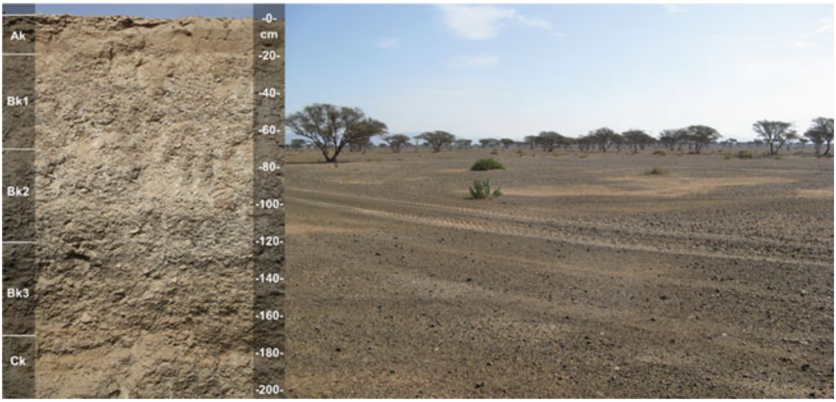


Fig. 5.4 Soilscape showing Typic Haplocalcids (NE015)

5.3.1.2 Petrocalcids

Key to Subgroups

Petrocalcids that have a calcic horizon overlying the petrocalcic horizon.

Calcic Petrocalcids

Other Petrocalcids that have a petrocalcic horizon within 100 cm of the soil surface and lack all other characteristics of any other subsurface horizon (Fig. 5.5).

Typic Petrocalcids

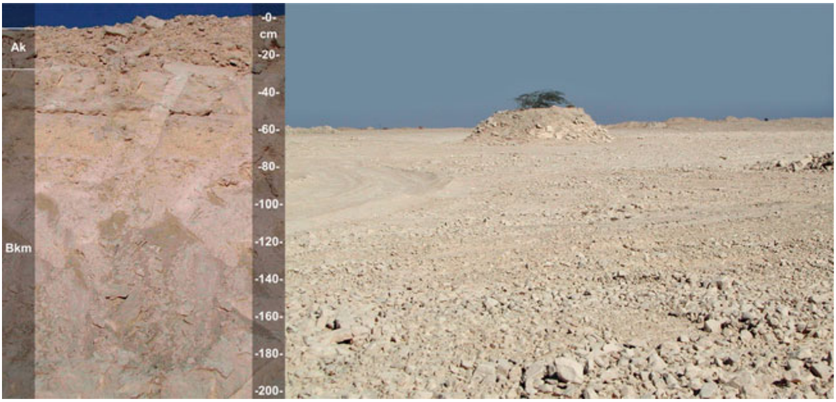


Fig. 5.5 Soilscape showing Typic Petrocalcids (AD106)

5.3.2 Cambids

Key to Great Groups
The soils that are the most extensive of the Cambids and do not have aquic conditions (within 100 cm of soil surface), a duripan or a petrocalcic or petrogypsic horizon within 150 cm of the soil surface, and do not have an anthropic epipedon.

Haplocambids, p. 56

5.3.2.1 Haplocambids

Key to Subgroups
Haplocambids that have, in a horizon at least 25 cm thick within 100 cm of the soil surface, an exchangeable sodium percentage of 15 or more (or an SAR of 13 or more) during at least 1 month in normal years.

Sodic Haplocambids

Other haplocambids that have an irregular decrease in organic-carbon content (Holocene age) between a depth of 25 cm and either a depth of 125 cm below the mineral soil surface or a densic, lithic, or paralithic contact, whichever is shallower.

Fluventic Haplocambids

Other Haplocambids that lack all other characteristics (Fig. 5.6).

Typic Haplocambids

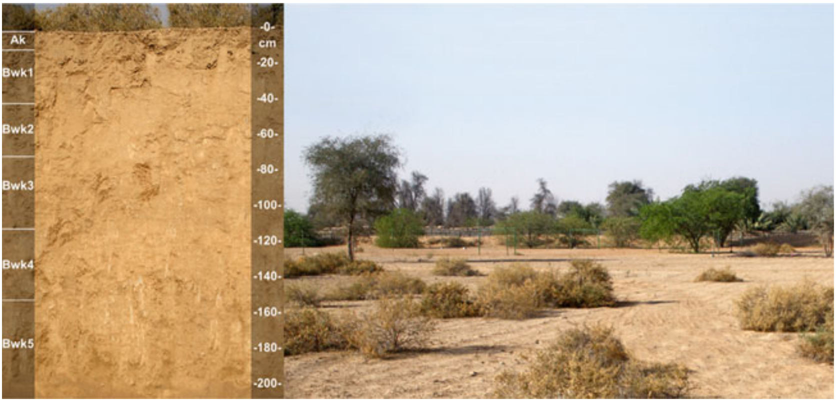


Fig. 5.6 Soilscape showing Typic Haplocambids (NE019)

5.3.3 Gypsids

Key to Great Groups

Gypsids that have a petrogypsic or petrocalcic horizon within 100 cm of the soil surface.

Petrogypsids, p. 61

Other Gypsids that have a calcic horizon within 100 cm of the soil surface.

Calcigypsids, p. 57

Other Gypsids that have only a gypsic horizon within 100 cm of the soil surface.

Haplogypsids, p. 59

5.3.3.1 Calcigypsids

Key to Subgroups

Calcigypsids that have a lithic contact within 50 cm of the soil surface (Fig. 5.7).

Lithic Calcigypsids

Other Calcigypsids that have an ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface (Fig. 5.8).

Salidic Calcigypsids

Fig. 5.7 Soilscape showing Lithic Calcigypsids (AD207)

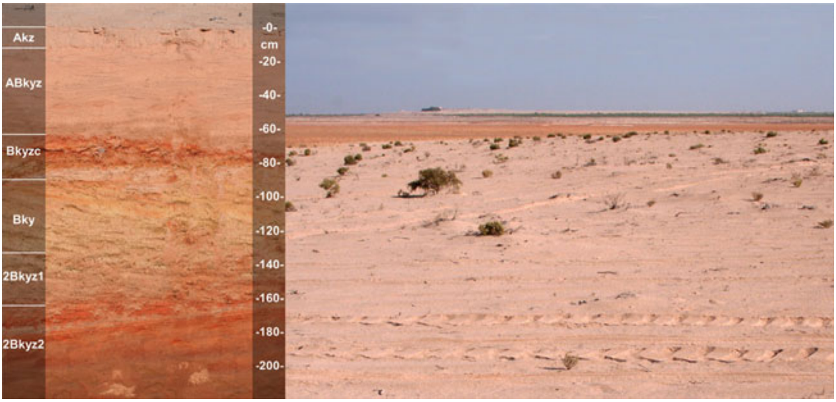


Fig. 5.8 Soilscape showing Salidic Calcigypsids (AD232)

Other Calcigypsids that lack all other diagnostic characteristics. These soils represent the central concept of the great group.

Typic Calcigypsids

5.3.3.2 Haplogypsids

Key to Subgroups
Haplogypsids that have:

1. An ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface: *and*
2. A lithic contact within 50 cm of the soil surface.

Salidic Lithic Haplogypsids

Other Haplogypsids that have a lithic contact within 50 cm of the soil surface (Fig. 5.9).

Lithic Haplogypsids

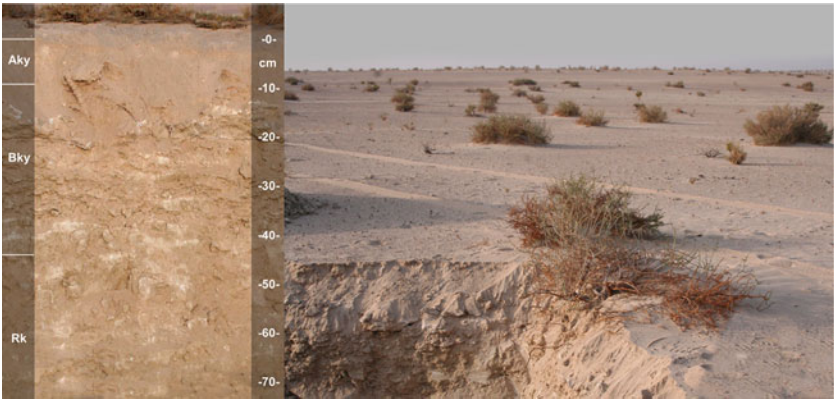


Fig. 5.9 Soilscape showing Lithic Haplogypsids (AD215)

Other Haplogypsids that have:

1. An ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface: and
2. A gypsic horizon within 18 cm of the soil surface.

Salidic Leptic Haplogypsids

Other Haplogypsids that have a gypsic horizon within 18 cm of the soil surface (Fig. 5.10).

Leptic Haplogypsids

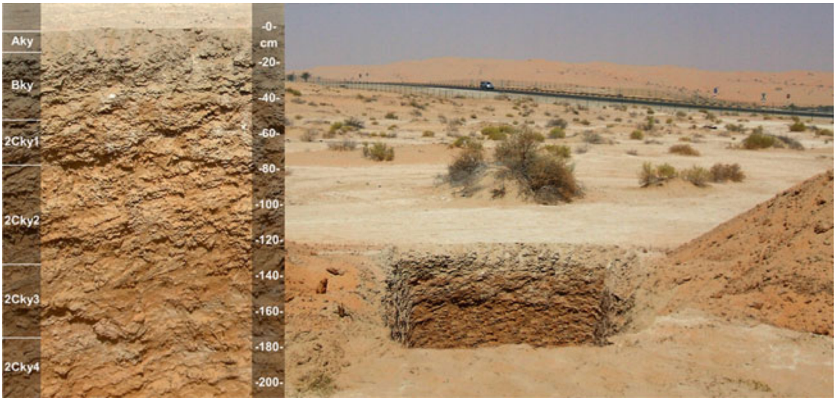


Fig. 5.10 Soilscape showing Leptic Haplogypsids (AD112)

Other Haplogypsids that have an ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface.

Salidic Haplogypsids

Other Haplogypsids that have only a gypsic horizon and lack all other characteristics. These soils represent the central concept of the great group (Fig. 5.11).

Typic Haplogypsids

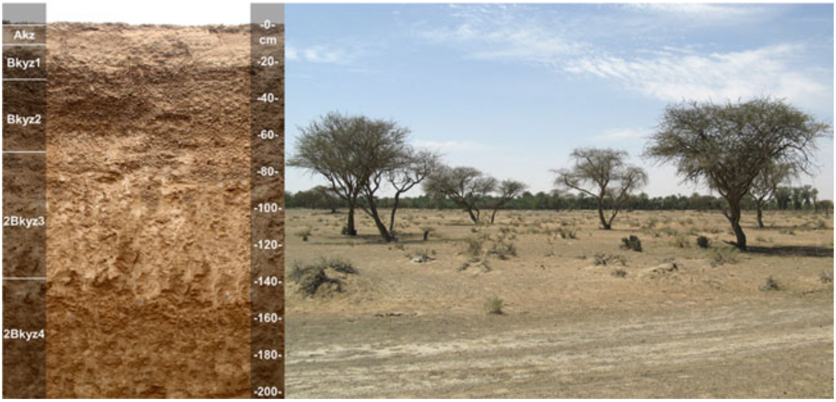


Fig. 5.11 Soilscape showing Typic Haplogypsids (NE022)

5.3.3.3 Petrogypsids

Key to Subgroups

Petrogypsids that have both:

1. An ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface: *and*
2. A lithic contact within 50 cm of the soil surface.

Salidic Lithic Petrogypsids

Other Petrogypsids that have lithic contact within 50 cm of the soil surface.

Lithic Petrogypsids

Other Petrogypsids that have both:

1. An ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface: *and*
2. A calcic horizon overlying the petrogypsic horizon (Fig. 5.12).

Salidic Calcic Petrogypsids

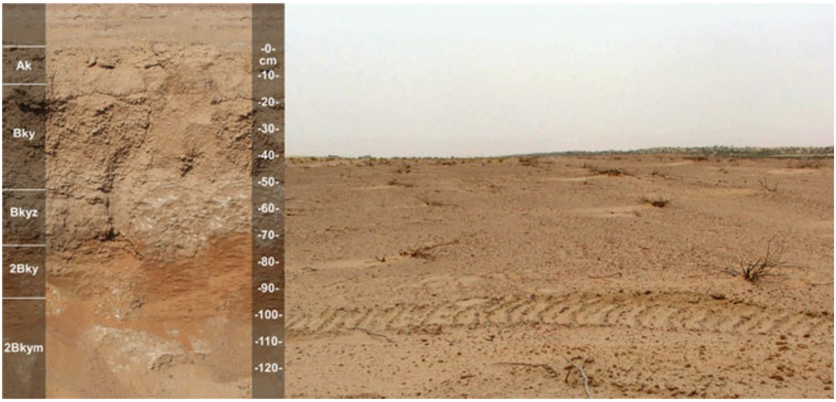


Fig. 5.12 Soilscape showing Salidic Calcic Petrogypsids (AD119)

Other Petrogypsids that have a calcic horizon overlying the petrogypsic horizon (Fig. 5.13).

Calcic Petrogypsids

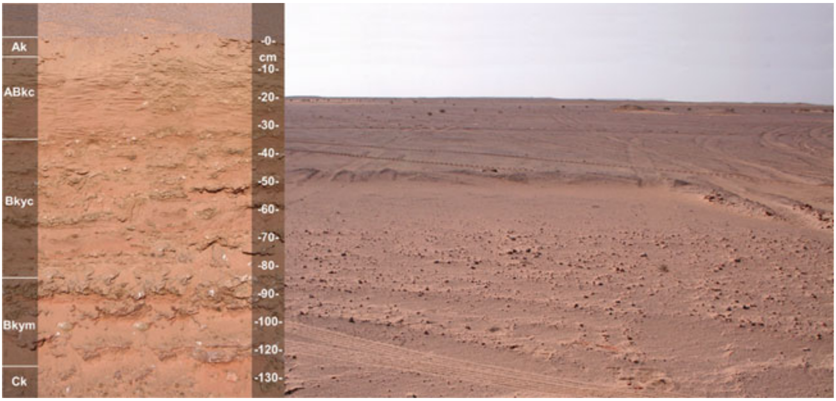


Fig. 5.13 Soilscape showing Calcic Petrogypsids (AD221)

Other Petrogypsids that have an ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface (Fig. 5.14).

Salidic Petrogypsids

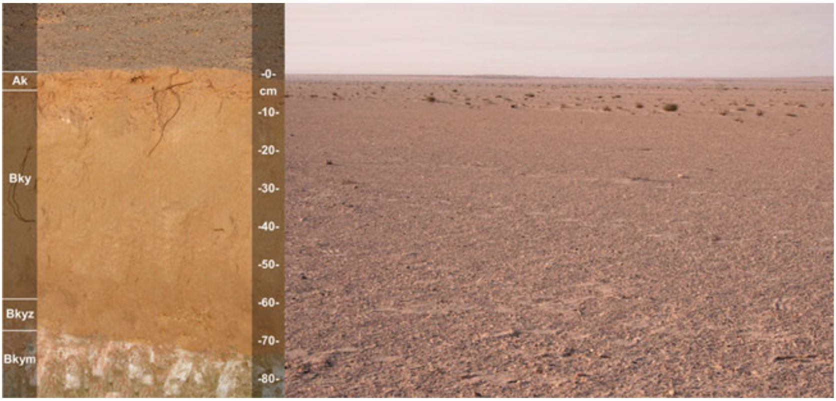


Fig. 5.14 Soilscape showing Salidic Petrogypsids (AD227)

Other Petrogypsids that have only a petrogypsic horizon and lack all other diagnostic subsurface horizons or characteristics. These soils represent the central concept of the great group (Fig. 5.15).

Typic Petrogypsids

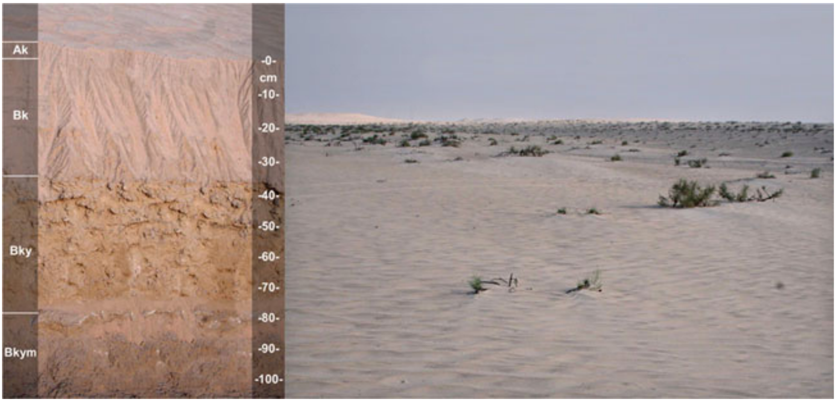


Fig. 5.15 Soilscape showing Typic Petrogypsids (AD226)

5.3.4 Salids

Key to Great Groups

Salids that are saturated with water in one or more layers within 100 cm of the mineral soil surface for 1 month or more in normal years.

Aquisalids, p. 63

Other Salids that are not saturated with water in one or more layers within 100 cm of the mineral soil surface for 1 month or more in normal years.

Haplosalids, p. 66

5.3.4.1 Aquisalids

Key to Subgroups

Aquisalids that have both:

1. A gypsic or petrogypsic horizon with its upper boundary within 100 cm of the soil surface, *and*

2. Lithic contact within 50 cm of the soil surface.

Gypsic Lithic Aquisalids

Other Aquisalids that have a lithic contact within 50 cm of the soil surface (Fig. 5.16).

Lithic Aquisalids

Fig. 5.16 Soilscape showing Lithic Aquisalids (NE 026)

Other Aquisalids that have a petrogypsic horizon with its upper boundary within 100 cm of the soil surface (Fig. 5.17).

Petrogypsic Aquisalids

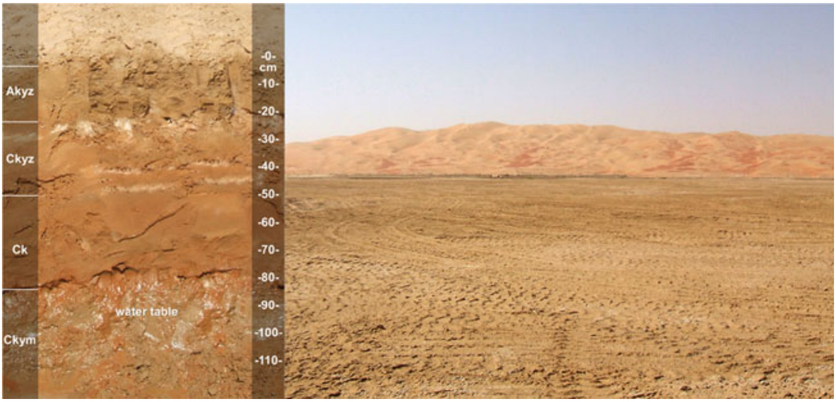


Fig. 5.17 Soilscape showing Petrogypsic Aquisalids (AD143)

Other Aquisalids that have an anhydritic horizon with its upper boundary within 100 cm of the soil surface (Fig. 5.18).

Anhydritic Aquisalids

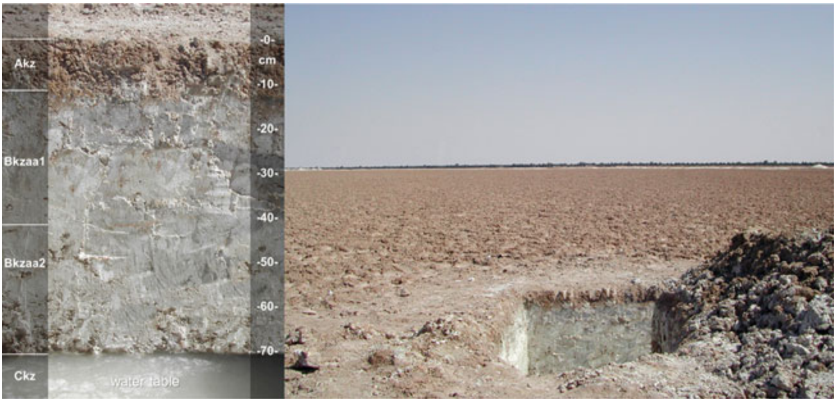


Fig. 5.18 Soilscape showing Anhydritic Aquisalids (AD125)

Other Aquisalids that have a gypsic horizon with its upper boundary within 100 cm of the soil surface (Fig. 5.19).

Gypsic Aquisalids

Fig. 5.19 Soilscape showing Gypsic Aquisalids (NE025)

Other Aquisalids that only have a salic horizon and do not have lithic contact within 50 cm of the soil surface or an anhydritic, calcic, gypsic, petrocalcic, or petrogypsic horizon that has its upper boundary within 100 cm of the soil surface. These soils represent the central concept of the great group (Fig. 5.20).

Typic Aquisalids

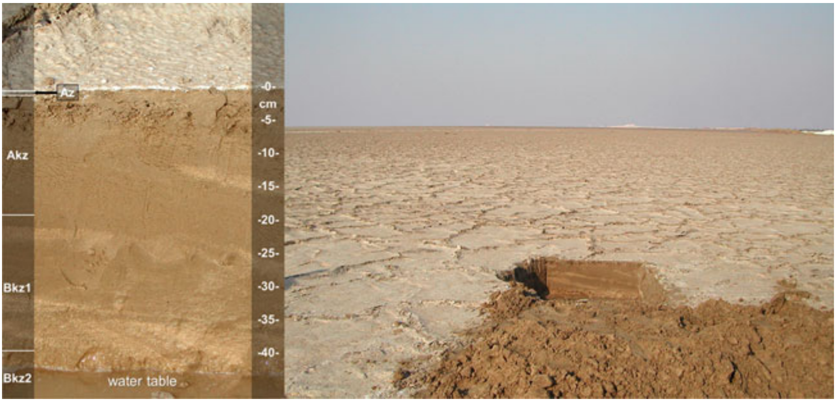


Fig. 5.20 Soilscape showing Typic Aquisalids (AD128)

5.3.4.2 Haplosalids

Key to Subgroups

Haplosalids that have both:

1. An overlying petrogypsic horizon: *and*
2. A lithic contact within 50 cm of the soil surface (Fig. 5.21).

Petrogypsic Lithic Haplosalids

Other Haplosalids that have *both*:

1. An overlying gypsic horizon: *and*
2. A lithic contact within 50 cm of the soil surface (Fig. 5.22).

Gypsic Lithic Haplosalids

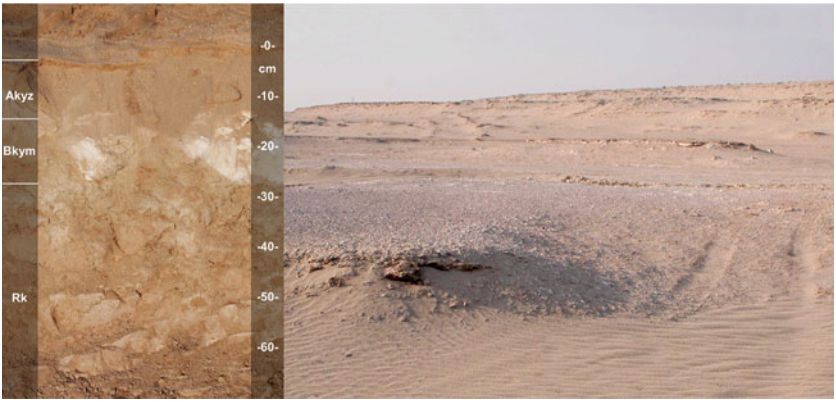


Fig. 5.21 Soilscape showing Petrogypsic Lithic Haplosalids (AD235)

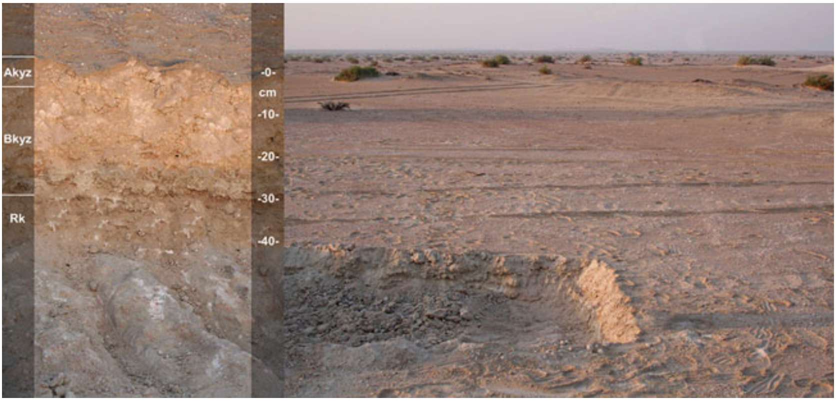


Fig. 5.22 Soilscape showing Gypsic Lithic Haplosalids (AD234)

Other Haplosalids that have *both*:

1. An overlying calcic horizon: *and*
2. A lithic contact within 50 cm of the soil surface (Fig. 5.23).

Calcic Lithic Haplosalids

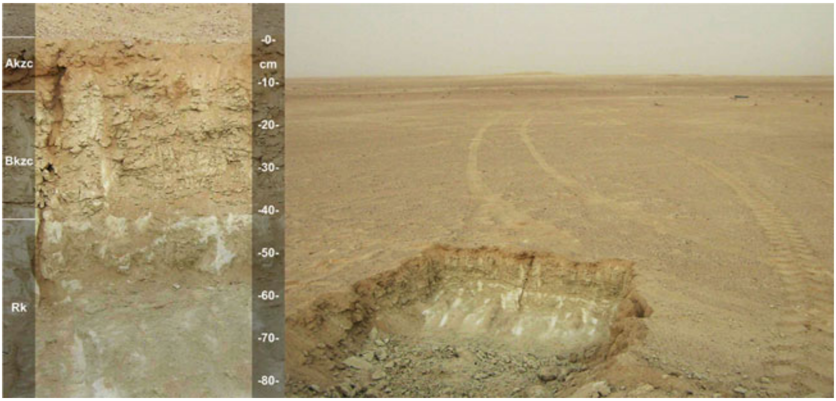


Fig. 5.23 Soilscape showing Calcic Lithic Haplosalids (AD230)

Other Haplosalids that have a lithic contact within 50 cm of the soil surface (Fig. 5.24).

Lithic Haplosalids

Fig. 5.24 Soilscape showing Lithic Haplosalids (AD239)

Other Haplosalids that have a petrogypsic horizon within 100 cm of the soil surface (Fig. 5.25).

Petrogypsic Haplosalids

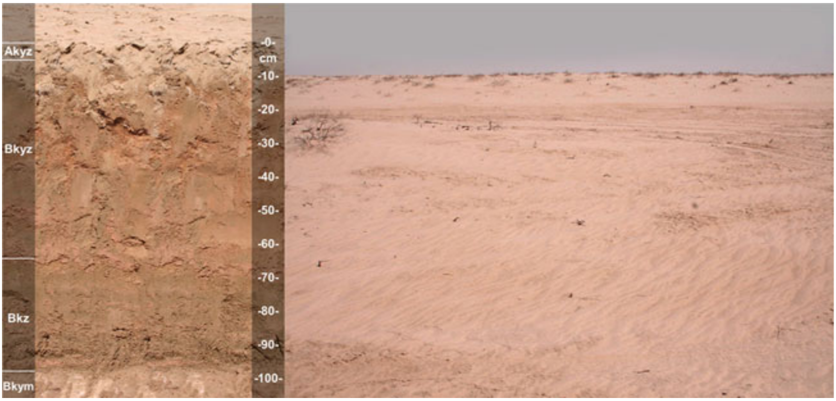


Fig. 5.25 Soilscape showing Petrogypsic Haplosalids (AD236)

Other Haplosalids that have an anhydritic horizon within 100 cm of the soil surface.

Anhydritic Haplosalids

Other Haplosalids that have a gypsic horizon within 18 cm of the soil surface.

Leptic Gypsic Haplosalids

Other Haplosalids that have a gypsic horizon at a depth of more than 18 cm to less than 100 cm from the soil surface (Fig. 5.26).

Gypsic Haplosalids

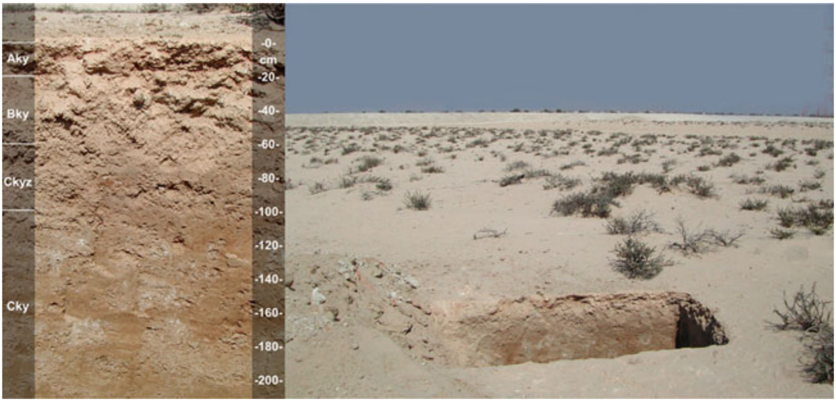


Fig. 5.26 Soilscape showing Gypsic Haplosalids (AD110)

Other Haplosalids that have a calcic horizon within 100 cm of the soil surface.

Calcic Haplosalids

Other Haplosalids that have only a salic horizon. These soils represent the central concept of the great group (Fig. 5.27).

Typic Haplosalids

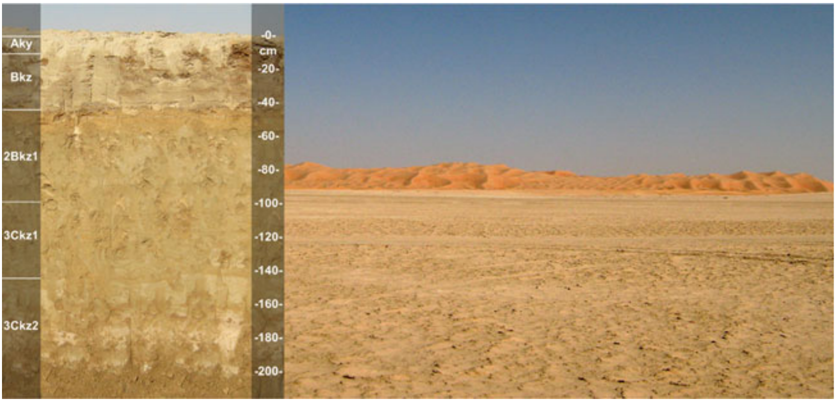


Fig. 5.27 Soilscape showing Typic Haplosalids (AD145)

5.4 Key to the Suborders of Entisols

Entisols that have permanent saturation with water and a reduced matrix in all horizons below 25 cm from the mineral soil surface.

Aquents, p. 71

Entisols that have less than 35 % (by volume) rock fragments and a texture class of loamy fine sand or coarser in all layers (sandy loam lamellae are permitted) within the particle-size control section.

Psamments, p. 74

Other Entisols that occur on recent erosional surfaces. As such they typically represent soils that display a high content of rock fragments or, as in some cases in the UAE, shell fragments. The soils are sandy or loamy in texture, are well drained, and in some places overlie calcified bedrock.

Orthents, p. 71

5.4.1 Aquents

Key to Great Groups

Aquents that have less than 35% (by volume) rock fragments and a textural class of loamy fine sand or coarser in all layers (sandy loam lamellae are permitted) within the particle-size control section.

Psammaquents, p. 71

5.4.1.1 Psammaquents

Key to Subgroups

Psammaquents that have an ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface.

Salidic psammaquents

Psammaquents that represent central concept of great group, and lack the characteristics of other psammaquents (Lithic, sodic, spodic, humaqueptic, mollic).

Typic psammaquents

5.4.2 Orthents

Key to Great Groups

Orthents that have an aridic (or torric) soil moisture regime.

Torriorthents, p. 71

5.4.2.1 Torriorthents

Key to Subgroups

Torriorthents that have a lithic contact within 50 cm of the soil surface and an ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface (Fig. 5.28).

Salidic Lithic Torriorthents

Other Torriorthents that have a lithic contact within 50 cm of the soil surface (Fig. 5.29).

Lithic Torriorthents

Other Torriorthents that have an ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface (Fig. 5.30).

Salidic Torriorthents

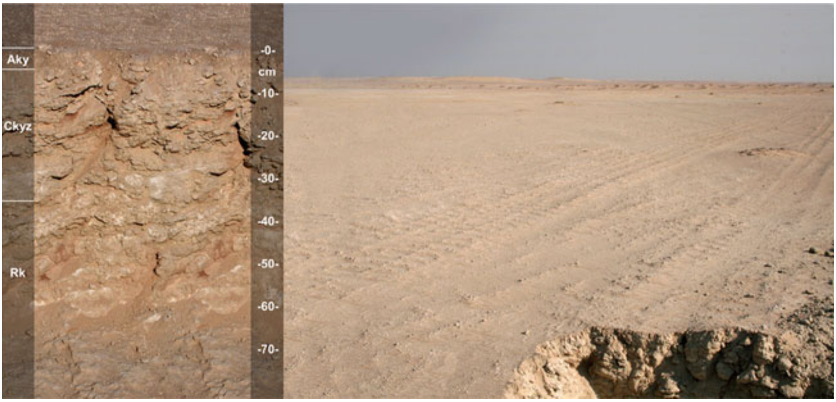


Fig. 5.28 Soilscape showing Salidic Lithic Torriorthents (AD240)

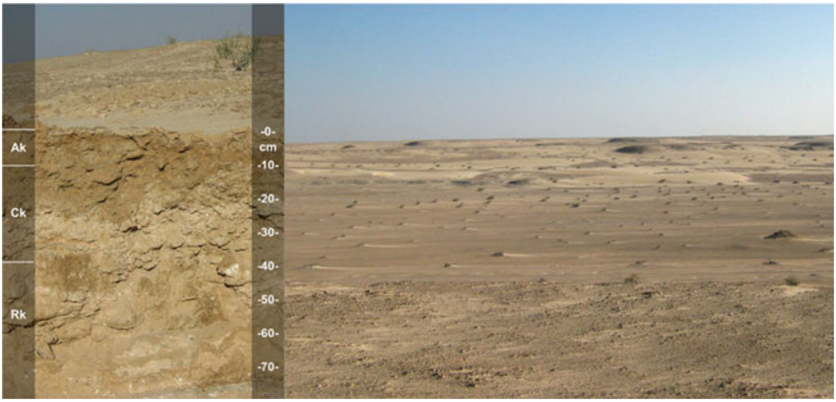


Fig. 5.29 Soilscape showing Lithic Torriorthents (AD150)

Other Torriorthents that have, in a horizon at least 25 cm thick within 100 cm of the mineral soil surface, an exchangeable sodium percentage of 15 or more (or an SAR of 13 or more) during at least 1 month in normal years.

Sodic Torriorthents

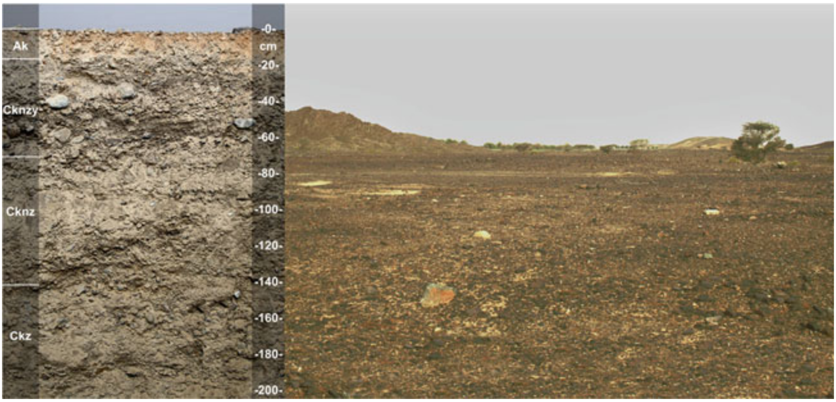


Fig. 5.30 Soilscape showing Salidic Torriorthents (NE005)

Other Torriorthents that lack all other diagnostic characteristics. These are the soils that represent the central concept of the great group. They are typically moderately deep or deep, well drained, gravelly soils (Fig. 5.31).

Typic Torriorthents

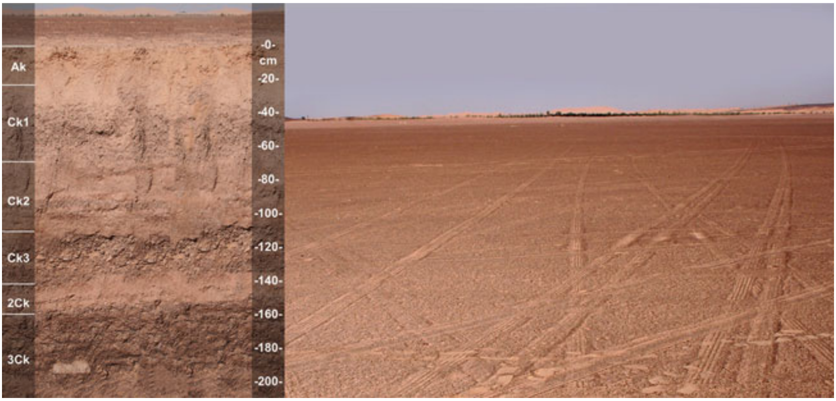


Fig. 5.31 Soilscape showing Typic Torriorthents (AD151)

5.4.3 Psamments

Key to Great Groups

Psamments that have an aridic (or torric) soil moisture regime and do not have moisture available for plants for long periods.

Torripsamments, p. 74

5.4.3.1 Torripsamments

Key to Subgroups

Torripsamments that have *both*:

1. An ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface: *and*
2. A lithic contact within 50 cm of the soil surface.

Salidic Lithic Torripsamments

Other Torripsamments that have a lithic contact within 50 cm of the soil surface (Fig. 5.32).

Lithic Torripsamments

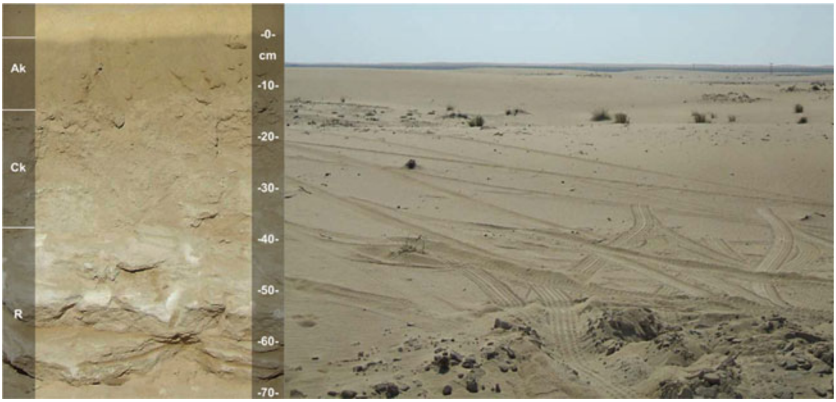


Fig. 5.32 Soilscape showing Lithic Torripsamments (AD152)

Other torripsamments that are saturated with water in one or more layers within 150 cm of the mineral soil surface in normal years for *either or both*:

1. 20 or more consecutive days; *or*
2. 30 or more cumulative days.

Oxyaquic Torripsamments

Other Torripsamments that have an ECe of more than 8 to less than 30 dS m^{-1} in a layer 10 cm or more thick, within 100 cm of the soil surface (Fig. 5.33).

Salidic Torripsamments

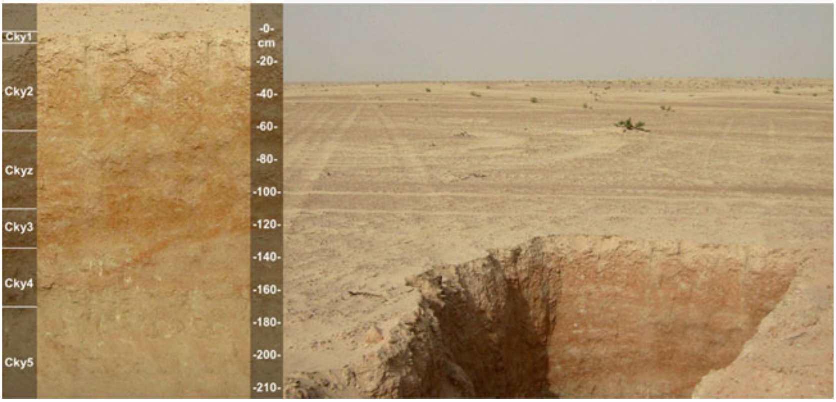


Fig. 5.33 Soilscape showing Salidic Torripsamments (AD246)

Other torripsamments that have, in a horizon at least 25 cm thick within 100 cm of the mineral soil surface, an exchangeable sodium percentage of 15 or more (or an SAR of 13 or more) during at least 1 month in normal years.

Sodic Torripsamments

Other Torripsamments that lack all other diagnostic characteristics. These are the soils that represent the central concept of the great group. They are deep and have a texture of sand or loamy sand throughout the top 100 cm of the profile. They are nonsaline and are always calcareous to various degrees but do not have enough pedogenic carbonate accumulation to form a calcic horizon. They are the most extensive soils in the United Arab Emirates (Fig. 5.34).

Typic Torripsamments

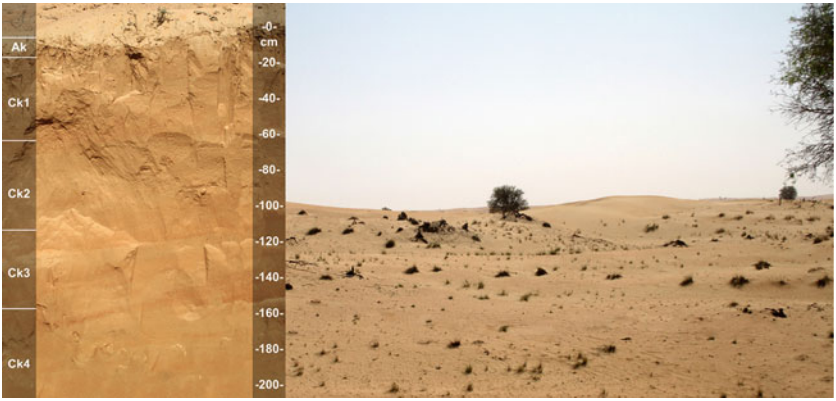
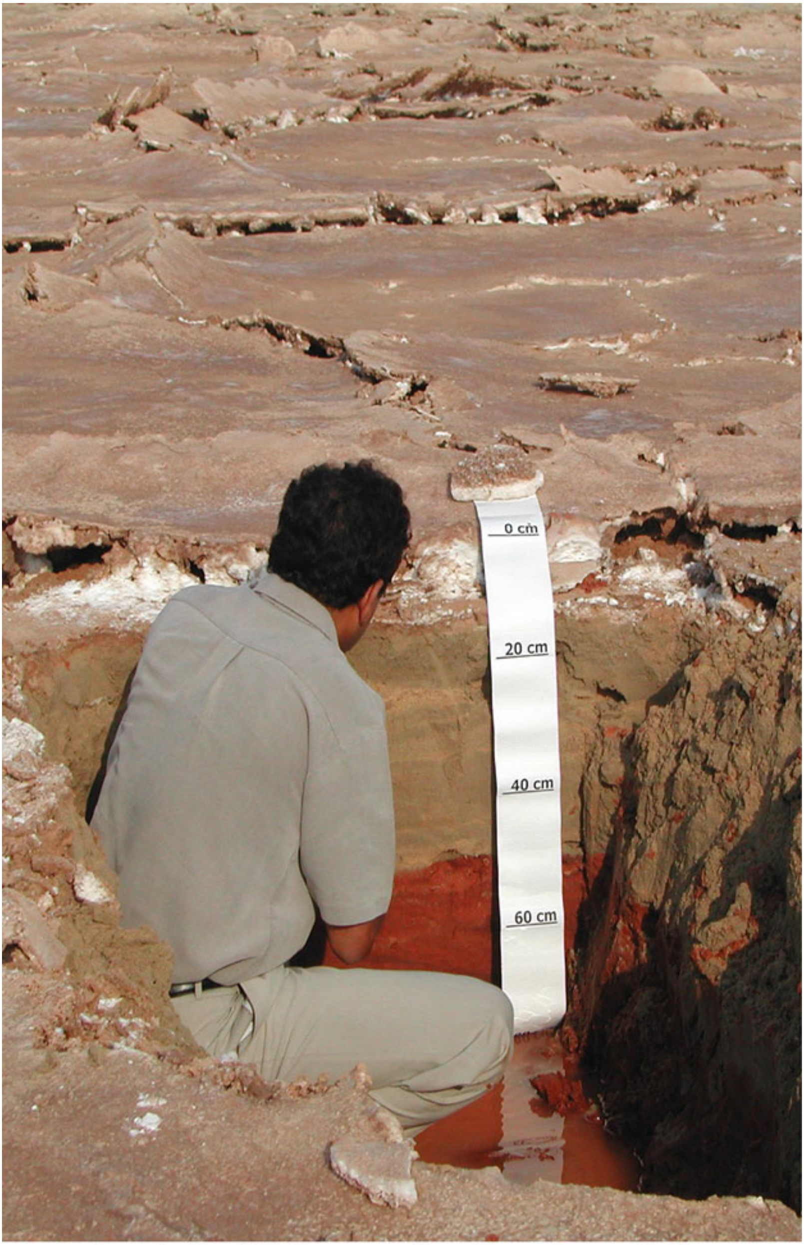


Fig. 5.34 Soilscape showing Typic Torripsamments (NE011)

Reference

Soil Survey Staff. (2010). *Keys to soil taxonomy* (11th ed.). Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service, U.S. Government Printing Office.



Investigation of shallow water table and strongly crusted saline scald (aquisalids) in the coastal area

Laboratory soil analysis supports final establishment of soil taxa

Laboratory Methods for Classification of United Arab Emirates Soils

6

Abstract

Laboratory analyses of soil samples are necessary to verify field soil taxonomic observation. The standard laboratory methods (physical, chemical, engineering, mineralogical, and micromorphological) that form the basis of the operational definitions of the second edition of Soil Taxonomy are described in this chapter, and these methods have been used to support the United Arab Emirates Keys to Soil Taxonomy. Some modifications have been made to fit the hot desert conditions in the United Arab Emirates. The procedures of various determinations such as soil texture, fragments in the soil, moisture content, total pretreatment loss (TPL), loss on acid treatment, carbonate equivalents, gypsum, anhydrite, extractable cations, cation-exchange capacity, exchangeable sodium percentage, saturation percentage, saturation extract analysis, electrical conductivity of the saturated extract, soil reaction or hydrogen ion activity (pH), sodium adsorption ratio, osmotic potential, engineering data (Atterberg limits), AASHTO group classification, Unified Soil Classification System (USCS), percent passing sieves, water retention, bulk density, particle density, porosity, organic carbon, soil mineralogy, clay mineralogy, x-ray fluorescence, thin section study (soil micromorphology) are described in this chapter.

Keywords

Laboratory procedures • Physical • Chemical • Mineralogical • Engineering • Micromorphological

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(Outside the USA) 2014

6.1 Introduction

Laboratory analyses of soil samples are necessary to verify field observation data, to determine properties and characteristics that cannot be estimated accurately by field observations, to help characterize typical profiles, and to properly classify soils. Laboratory procedures are routinely checked and closely monitored to ensure quality control. The standard laboratory methods that form the basis of the operational definitions of the second edition of *Soil Taxonomy* (Soil Survey Staff 1999) are described in the *Soil Survey Laboratory Methods Manual* (Burt 2004) and have been used to support the *United Arab Emirates Keys to Soil Taxonomy*. Some modifications have been made to fit the hot desert conditions in the United Arab Emirates. The following analyses (physical, chemical, engineering, mineralogical, and micromorphological) were carried out. Method codes cited are taken from Burt (2004).

6.1.1 Soil Texture

The texture of a soil is defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 mm in diameter (fine-earth fraction). After pretreatments to remove organic matter and gypsum and to disperse the soil:water suspension, the soil texture was assessed by determining the particle-size distribution. Very coarse (1–2 mm), coarse (0.5–1 mm), medium (0.25–0.5 mm), fine (0.1–0.25 mm), and very fine (0.05–0.1 mm) sands were determined by wet sieving and oven drying the sand fractions retained on each sieve. Coarse silt (0.02–0.05 mm), fine silt (0.002–0.02 mm), and clay (<0.002 mm) were determined from an oven-dried aliquot of suspended soil collected by pipette at specified timings of sedimentation based on Stoke's Law. Results are presented as weight percentages of the fraction less than 2 mm on an oven-dry soil basis, including carbonates and excluding gypsum. Using the proportions of the sand, silt, and clay fractions, the soil texture class was determined using USDA specifications (Soil Survey Division Staff 1993).

6.1.2 Fragments in the Soil

The fraction which is 2 mm or larger in diameter are fragments in the soil. These fragments include rock fragments (i.e., geologic origin), shells, and carbonate nodules, but exclude gypsum crystals, and were determined by a dry sieving procedure. The weights of the material that would not pass sieves with apertures of 5, 20, and 75 mm were recorded.

6.1.3 Moisture Content

A known quantity of air-dried sample was weighed, dried to a constant weight in an oven at 110 ± 5°C, and reweighed. Moisture content of gypsiferous soils that are reported on an oven-dry weight basis was adjusted to remove the weight of the crystal water (methods 2D1-3 and 3D1-3).

6.1.4 Total Pretreatment Loss (TPL)

Carbonates were dissolved by heating the soils to approximately 90 °C in a NaOAc solution (buffered to pH 5). The undissolved soil was then separated from the NaOAc solution, and the soil sample treated with H_2O_2 for oxidation of organic matter. Distilled water was then added to remove soluble gypsum. The residual sample was oven-dried overnight. The loss in sample weight (due to removal of carbonates, organic matter, and gypsum) is calculated and reported as a percentage on a <2 mm basis. This method is based on method 3A1a1a (steps 7.5–7.10) and method 3A1a2a

6.1.5 Loss on Acid Treatment (LAT)

A known quantity of sample was treated with HCl to destroy carbonates. The loss in weight is expressed as calcium carbonate on an oven-dry basis, <2 mm basis (based on method 6E1c). The data are a useful check on the accuracy of the carbonate equivalents analysis.

6.1.6 Calcium Carbonate Equivalents

The quantity of calcium carbonate equivalent is required in soil taxonomy to identify a calcic diagnostic horizon and to determine anhydritic, carbonatic, and gypsic mineralogy classes. The amount of carbonate in the soil was measured by treating the samples with HCl. The evolved CO_2 was measured manometrically using a calcimeter. The amount of carbonate was then calculated as percent $CaCO_3$ equivalent regardless of the form of carbonates (dolomite, sodium carbonate, magnesium carbonate, etc.) in the sample (method 4E1a1a1a1).

6.1.7 Gypsum

Gypsum ($CaSO_4.2H_2O$) content of a soil is a criterion for gypsic and petrogypsic horizons and for particle-size and mineralogical classes at the family level (Soil Survey Staff 1999). Gypsum was measured by reacting a soil extract with acetone, the precipitated calcium sulfate was dissolved in water and EC was measured enabling gypsum percentage to be derived from a calibration curve (method 4E2a1a1a1).

6.1.8 Anhydrite

Anhydrite ($CaSO_4$) is quantified by the difference in two analytical procedures. Anhydrite and gypsum are both extracted and measured by the acetone procedure (method 4E2a1a1a1). Gypsum (but not anhydrite) is quantified by thermal gravimetric analysis, a method that measures the weight loss of a sample by heating it from 20 °C to 200 °C at a rate of 2 °C per minute. The weight of water lost between 75 °C and 115 °C is used to quantify the gypsum based on a theoretical weight loss of 20.9 % (Karathanasis and Harris 1994). Finally, the percent anhydrite is equal to the difference between the acetone and thermal procedures.

6.1.9 Extractable Cations

The soil sample was reacted with 1 N NH_4OAc to replace exchangeable cations. The solution was then separated through centrifugation, and the extracted Na, K, Ca, and Mg were determined using Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) and expressed as meq/100 g (Thomas 1982). For SI conversion the units can be considered as 1 meq/100 g = 1 cmol(+)/kg.

6.1.10 Cation-Exchange Capacity (CEC)

Cation-exchange capacity is a measure of the ability of a soil to hold and exchange cations in a plant available form (e.g., Ca, Mg, Na, NH_4, and K). It is one of the most important chemical properties of soil. This method was based on saturation of cation-exchange sites with Na by “equilibration” of the soil with 1 N NaOAc solution buffered at pH 8.2 and washing with 95 % ethanol. The extraction of sodium was carried out with 1 N ammonium acetate solution (pH 7). The extracted Na was then determined using ICP-AEC and expressed as the CEC in meq/100 g

(USDA 1954). For SI conversion the units can be considered as 1 meq/100 g = 1 cmol(+)/kg.

6.1.11 Exchangeable Sodium Percentage (ESP)

Exchangeable sodium percentage was calculated using the relationship given by the U.S. Salinity Laboratory Staff (USDA 1954) for estimating ESP of saturation extract from SAR for soils with CEC less than 50 meq/100 g: $[100 \times (-0.0126 + 0.01475 \times \mathrm{SAR})/(1 + (-0.0126 + 0.01475 \times \mathrm{SAR})]$.

6.1.12 Saturation Percentage (SP)

The saturation percentage provides indication of available water contents in soil and is also a prerequisite for converting soil solution chemistry data (in water) to soil weight basis. A 250 g air-dried soil sample was saturated with water, taking care to ensure that the resulting soil/water mix met the criteria for a saturated paste. The volume of water and weight of soil were used to calculate the saturation percentage (SP) (method 4 F2).

6.1.13 Saturation Extract Analysis

The solution in the saturated paste was separated from the soil by vacuum extraction and filtration and analyzed for the following characteristics (methods 4F2c1a1 to 4): soluble Ca^{2+}, Mg^{2+}, Na^+, and K^+ were measured by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES). Soluble HCO_3^- by titration with 0.011 N H_2SO_4 in the presence of methyl orange indicator, CO_3^{2-} by titration with 0.011 N H_2SO_4 in the presence of phenolphthalein indicator, and soluble Cl^-, NO_3^-, PO_4^{3-}, and SO_4^{2-} by ion chromatography.

6.1.14 Electrical Conductivity of the Saturated Extract (ECe)

The ECe is a standard representation of an indirect measurement of soil salinity (soluble salts commonly composed of contain Ca^{2+}, Mg^{2+}, Na^+, and K^+, HCO_3^-, CO_3^{2-}, Cl^-, and SO_4^{2-}). The ECe is measured with a standard EC meter and reported as deci Siemens/meter (dS m^{-1}).

6.1.15 Soil Reaction or Hydrogen Ion Activity (pH)

The soil reaction is an expression of the degree of acidity or alkalinity of a soil and is expressed as pH. The pH of saturated soil paste (pHs) is measured with a standard pH meter calibrated using buffer solutions of pH 4.0, 7.0, and 10.0.

6.1.16 Sodium Adsorption Ratio (SAR)

The SAR is a measure of the activities of sodium relative to calcium and magnesium in the soil saturation extract. It is an indirect measure of the equilibrium relation between sodium in the salt solution and exchangeable sodium adsorbed on the soil exchange complex. The SAR was calculated by standard formula (method 4F3b): $\mathrm{SAR} = \mathrm{Na}/[(\mathrm{Ca} + \mathrm{Mg})/2]^{0.5}$, using inputs for the water soluble cations expressed as milliequivalents per liter (meq L^{-1}), and SAR expressed as (mmoles $\mathrm{L}^{-1})^{0.5}$.

6.1.17 Osmotic Potential (OP)

Osmotic potential (atmospheres) provides a guide to the energy a plant must expend to extract water from soil solution; a more saline solution requires more energy. The ECe value was used to estimate the osmotic potential in atmospheres of a solution (USDA 1954) as $\mathrm{OP} \approx 0.36 \times \mathrm{ECe}$ where ECe is expressed as dS m^{-1}.

6.1.18 Engineering Data

The soils can be analyzed for their Atterberg limits and classified for engineering purposes according to the Unified Soil Classification System (USCS) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO).

6.1.19 Atterberg Limits

Atterberg limits are determined on the fraction less than 0.4 mm in size. Atterberg limits are soil water contents that define the upper and lower boundaries of the plastic state for a given soil. They provide basic measures of the engineering behavior of fine-grained soil and include the plastic limit (Wp) and liquid limit (Wl) and plasticity index (Ip), which is the difference in water content between the liquid limit and plastic limit. The plastic limit is determined by rolling a soil sample into 3.2 mm diameter thread. This thread is broken into pieces, squeezed together again, and rolled until its water content is reduced to a point at which the thread crumbles and can no longer to be pressed and rolled. At this point the water content of soil is reported as the plastic limit. Liquid limit is determined by performing observations in which a portion of sample is spread in a brass cup, divided in two by a grooving tool, and then allowed to flow together by repeatedly dropping the cup in a uniform manner in the standard mechanical liquid limit device. The multipoint liquid limit procedure requires the performance of three or more observations over a range of water contents and the plotting of data from the trials to obtain the relationship from which the liquid limit is determined (ASTM D 4318–2004).

6.1.20 AASHTO Group Classification

The AASHTO group classification is based upon particle-size distribution and Atterberg limits. The system is used for geotechnical engineering purposes to make general interpretations relating to the engineering performance of soils for construction and load bearing purposes.

The system identifies two general groups:

- Granular materials having 35 % or less, by weight, particles smaller than 0.074 mm in diameter; and
- Silty-clay materials having more than 35 %, by weight, particles smaller than 0.074 mm in diameter.

These two groups are further subdivided into seven main subgroup classifications. The group and subgroup classifications are based on estimated or measured grain-size distribution and on liquid limit and plasticity index values derived from measured values of samples taken from typical profiles.

The AASHTO group and subgroup classifications may be further modified by the addition of a group index value. The empirical group index formula was devised for approximate within-group evaluation of "clayey granular materials" and "silty-clay" materials. The dominant AASHTO group classifications for UAE soils and their inherent characteristics are:

A-3: Silty sand with a maximum of 10 % silt. Typically nonplastic. These soils are suitable for structural and general backfill material.

A-2-4: Silty sand with a maximum silt content of 35 %. The material is either nonplastic or has a low plasticity. The high sand content allows the soils to be classified as structural fill material and hence used for general engineering purposes (herein defined as construction and earthworks purposes).

A-1-b: These soils contain stone fragments and up to 25 % fines (very fine sand, silt, and clay). They are either nonplastic or slightly plastic. They are suitable as general backfill for engineering purposes.

A-1-a: These soils are similar to those classified as A-1-b but are limited by the high percentage of stone fragments.

6.1.21 Unified Soil Classification System (USCS)

The USCS is a system for classifying mineral and organic soils for engineering purposes based on particle-size characteristics, the amounts of various sizes, and the characteristics of the very fine particles assessed by the liquid limit and plasticity index.

The USCS identifies three major soil divisions:

(i) coarse-grained soils having less than 50 %, by weight, particles smaller than 0.074 mm in diameter;
(ii) fine-grained soils having 50 % or more, by weight, particles smaller than 0.074 mm in diameter; and
(iii) highly organic soils that demonstrate certain organic characteristics.

These divisions are further subdivided into 15 basic soil groups. The major soil divisions and basic soil groups are determined on the basis of estimated or measured values for grain-size distribution and Atterberg limits. The various groupings of the USCS classification have been devised to correlate with the engineering behavior of soils. This correlation provides a useful first step in any field or laboratory investigation of soils for engineering purposes. The classification and its interpretation are applicable in the design of foundations for a range of structures. The dominant USCS classifications for UAE soils and their inherent characteristics are:

SM: Silty sand with a maximum of 30 % fine material that is nonplastic. These soils contain various cementing agents, such as calcium carbonate, gypsum, clay, and silt. The degree of cementation can range from noncemented to strongly cemented in both the horizontal and vertical directions (note that within the soil profile various horizons of SM material can exhibit differing degrees of cementation). From an engineering point of view, the soil would classify as SM.

SP-SM: Silty sand with fine material limited to between 5 % and 12 %. These soils contain various cementing agents, such as calcium carbonate, gypsum, clay, and silt.

The soils are relatively permeable due to poor gradation. These soils are suitable for general engineering purposes.

SP: Poorly graded or gap graded fine to medium sand with little or no fines; not recommended for engineering purposes; difficult to compact; suitable for highly permeable fill material. This is the most common category for UAE soils.

SW: Well graded siliceous sand with little or no fine material; very good material for construction and general engineering purposes. Rarely found in the study area.

CL: Inorganic clay. Typically mixed with sands with low plasticity and Wl <50 %. These soils are not common in the UAE. This material is considered unsuitable for general engineering purposes.

MH: Inorganic silts with high plasticity. Very rare in the UAE. This material is considered unsuitable for general engineering purposes.

CH: Inorganic clays with high plasticity. Very rare in the UAE. This material is considered unsuitable for general engineering purposes.

6.1.22 Percent Passing Sieves

An air-dried soil subsample can be sieved through a nest of sieves, mesh numbers 4 (4.75 mm), 10 (2 mm), 40 (0.42 mm), and 200 (0.074 mm), and shaken mechanically. The material retained on each sieve can be weighed, and calculations can be made using a standard formula (USDA-NRCS 1995) to represent percent soil passing the respective sieves.

6.1.23 Water Retention (WR)

Water retention is defined as the soil water content at a given soil water suction. By varying the soil suction and recording the changes in soil water content, a water retention function or curve is determined. A pressure membrane apparatus method (3C1ae) is used to determine water retention (percent) at 1/10, 1/3, and 15 bars, respectively, for sieved, <2 mm, air-dry soil samples. The following are SI conversions:

15 bar = 1,500 kPa
1/3 bar = 33 kPa
1/10 bar = 10 kPa

6.1.24 Water Retention Difference (WRD)

The calculation of the WRD is considered the initial step in the approximation of the available water capacity. The WRD can be calculated as the difference in water retentions at 33 and1,500 kPa, converted to units of mm by multiplying by bulk density and to a whole soil basis by multiplying by the proportion of soil that passes a 2 mm sieve (method 3D5a).

6.1.25 Bulk Density (BD)

Bulk density is the weight of soil (oven dry) per unit bulk volume of soil (volume occupied by soil solids and pore spaces). The bulk density of a soil indicates the pore space available for water and roots. For example, a bulk density of 1.6 g/cm^3 and higher can restrict water storage and root penetration. Bulk density samples can be collected in standard steel cores of known volume and then oven dried. The loss in weight on drying is recorded and bulk density calculated by standard formula (method 4A3a). Where bulk density is not measured but is required for calculating other properties, an estimated value (BDcalc) is derived from the sand content (TOTALSAND%) based on the following equation derived from UAE soil surveys data: $\text{BDcalc} = 0.0098 \times \text{TOTALSAND\%} + 0.657$

6.1.26 Particle Density (PD)

The particle density provides an understanding of the basic component particles of the soil. The method requires using a pycnometer to estimate the volume of water or an inert gas (e.g., He) displaced by a known weight of soil, ensuring that all air is removed from the mixture (method 3G). Where particle density has not been measured, a value of 2.65 g/cm^3 has been assumed as the basis of other calculations.

6.1.27 Porosity

The percent volume of bulk soil that is occupied by pore spaces (the space filled by air or water) is called porosity. Porosity is calculated by using a standard formula of $100\ (1-\text{BD}/\text{PD})$, where BD and PD represent the bulk density and particle density, respectively.

6.1.28 Organic Carbon (OC)

Organic carbon was determined by oxidizing the sample by flash combustion followed by reduction of gases produced. The product gases formed by reduction are separated chromatographically on a column using helium as carrier gas and detected using thermal conductivity detector (TCD). The percent organic carbon is converted to percent organic matter by multiplying by a factor of 1.724 (Burt 2004).

6.1.29 Soil Mineralogy (XRD Analysis)

The x-ray diffraction (XRD) is by far the most powerful technique to identify mineral species in soils. Whole soil mineralogy from the control sections of the typical soil profiles of identified soil families was determined by using a standard x-ray diffraction technique. The soil material was ground with an agate pestle and mortar and lightly pressed in an aluminum sample holder.

X-ray patterns were recorded using Cu-Kα radiation, using variable divergent, receiving and scattering slits. The step size was 1°2θ/min. The procedure is similar to method 7A2i (Burt 2004). A Philips x-ray diffraction model PW/1840, with Ni filter, Cu-Kα radiation ($\lambda = 0.154$ nm) at 40 kV, 55 mA, and scanning speed 0.02°/s, was used. Diffraction peaks between 2 and 60°2θ were recorded. The corresponding d-spacing and the relative intensities (I/Io) were calculated and compared with standard patterns (ASTM cards).

6.1.30 Clay Mineralogy (CM)

Clay (particles <2 μm) is a reactive (high surface area) soil component that controls physical, chemical, and nutritional behavior (nutrient storage) of soil and therefore affects agricultural potential. The clay-size material was separated from soil after the cementing material (organic matter, gypsum, and soluble salts) was removed for dispersion of clay in a soil suspension. Sedimentation and sampling for clay was based on Stoke's Law.

To resolve the clay mineral species, the clay was treated with K, K-heating at 300 °C and 550 °C, Mg, Mg ethylene glycol, and Mg-glycerol solvation. The treated clay samples were mounted on glass slides, and x-ray diffraction patterns were recorded using XRD equipment as above. The XRD patterns were interpreted for mineral species, comparing with standard reference patterns and measurements (ASTM cards). An additional test was made to confirm the presence of kaolinite using the Lim test (Lim et al. 1980). In this test the 7.2 Å peak of first order kaolinite shifts to 11.2 Å; however, second order chlorite peak remained at 7.00 Å. Based on the peak heights of the minerals, area under the peaks, and sharpness, the amounts of each mineral was estimated semiquantitatively (%).

6.1.31 X-ray Fluorescence (XRF)

A 1 g soil sample was ignited at 1,100 °C and dissolved in 9 g of lithium tetraborate and lithium borate (66:34) and 0.5 g of lanthanum oxide flux to form a disc for x-ray fluorescence analysis. The information is presented as percentages of elemental oxide.

6.1.32 Thin Section Study (Soil Micromorphology)

Undisturbed soil samples were collected in standard Kubiena boxes. Samples were dried and impregnated with a mixture of resin, acetone, and a hardener. On setting, the impregnated blocks were cut into small sections with a diamond saw and lubricant. The face of the section was polished with aloxite grit (6 μm) and then with diamond paste (6 and 3 μm) with Hyprez fluid as lubricant. It was then cleaned ultrasonically with petroleum spirit to remove residue from pores. The polished side was then stuck with adhesive on a clean slide and clamped to allow the adhesive layer to cure. The excess of the block was cut off with a diamond saw. The section was then ground initially to approximately 50 μm thickness on a lapping and polishing machine, then to 30 μm by hand grinding. The quartz grains were viewed in the microscope to observe the onset of gray birefringent color under crossed polars. Final polishing was completed with 6 and 3 μm diamond pastes followed by ultrasonic cleaning. Thin sections were studied on a petrographic microscope fitted with a digital camera, and the different components (groundmass, microstructure, mineral composition, pedofeatures, and pore space) were described using the procedures of Bullock et al. (1985) through point counting. Photographs of important features were captured using a digital camera fitted to the petrological microscope.

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Sandy deserts with some vegetation cover are attraction to grazers

Soil Families and Soil Series of the United Arab Emirates

7

Abstract

The US Soil Taxonomy hierarchy constitutes six levels (Order-suborder-great group-subgroup-family-soil series). In the UAE soil survey, soil family in the extensive survey and soil series in the intensive survey are recognized. The name of soil family and a soil series is used as a soil map unit component. There are 62 soil families and 19 soil families established with the correlation of extensive survey of Abu Dhabi Emirate and Dubai Emirate soil survey, respectively. There are a total of 74 soil series established with the correlation and publication of the soil surveys of the Abu Dhabi Emirate and the Northern Emirates. Salidic subgroup has been developed for the United Arab Emirates Keys to Soil Taxonomy and is recognized for the first time in this publication. In this chapter a list of the current identified soil families and soil series in the UAE and their official classification based on this Key are reported.

Keywords

Taxonomy • Hierarchy • Soil family • Soil series • Salidic • UAE

7.1 Introduction

The US soil taxonomy hierarchy constitutes of six levels (Order-suborder-great group-subgroup-family-soil series). The soil family in extensive survey of Abu Dhabi (EAD 2009a) and soil series are the lowest category of the UAE soil classification system (EAD 2009b, 2012). The soil family, name of soil series or their phases are the most common reference term used in soil map unit names, based on the scale and order of soil survey. The name of soil family and a soil series is also the most common reference term used as a soil map unit component.

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Soil series are the most homogeneous classes in the system of soil taxonomy and are the most common tool for communicating information about a particular soil type. As a general guide, a new soil series differs appreciably in either morphology or composition, or both, from already defined soil series. Differences in relevant characteristics must be larger than what may be normal errors of observation or estimates.

There are 62 soil families (Abu Dhabi Emirate), 19 soil families (Dubai Emirate) established with the correlation of extensive survey of Abu Dhabi Emirate (EAD 2009a) and Dubai Emirate soil survey (DM 2005) respectively (Tables 7.1 and 7.2). There are 74 soil series (Tables 7.3 and 7.4) established with the correlation and publication of the soil surveys of the Abu Dhabi Emirate (EAD 2009b) and the Northern Emirates (EAD 2012). At the time of publication of the soil surveys," shallow" families were assigned to those soils in the suborder of Salids with lithic contact within 50 cm of the soil surface. With the development of a soil classification system dedicated to the soils of the UAE, appropriate family criteria have been developed to identify these soils in a "Lithic" subgroup. These modifications have been incorporated into this publication and are proposed for revision to the USDA *Keys to Soil Taxonomy*.

Also, for those soils that have saline conditions within the upper 100 cm, a "saline" phase was assigned to the soil series name in the Abu Dhabi soil survey to recognize the high salt content. "Salidic" subgroups have been developed for the *United Arab Emirates Keys to Soil Taxonomy* and are recognized for the first time in this publication.

The Tables 7.1, 7.2, 7.3, and 7.4 provide a list of the current identified soil families and soil series in the UAE and their official classification based on this Key. Classification provided in the published soil survey reports is based on the version of the *Keys to Soil Taxonomy* that was current at the time of publication and may differ from the classification provided in Tables 7.1, 7.2, 7.3, and 7.4.

The soil series that are identified as "saline phase" (e.g., Saruk Qufa, saline phase) will be re-correlated to new soil series names. The column for "Soil Code" refers to the published soil families and soil series identifier. For example AD201 is the reference code assigned to the first soil series correlated in the *Soil Survey of Abu Dhabi Emirate-Intensive Survey* and NE001 is the first soil series correlated in the *Soil Survey of the Northern Emirates*.

It is assumed that when the surveyor keyed out the soil in the United Arab Emirates at the family or soil series levels, he/she will then correlate the information with Tables 7.1, 7.2, 7.3, and 7.4, which are providing soil codes for soil families and soil series as appeared in Soil Survey of Abu Dhabi Emirate (EAD 2009a, b), Dubai Emirate (DM 2005) and Soil Survey of Northern Emirates (EAD 2012). These survey reports present description of typical profiles following by soil analyses results, soil and thematic maps, mapping units and their component soils, as well as their interpretation for many uses.

Table 7.1 Soil families of the extensive soil survey of Abu Dhabi Emirate correlated to UAE Keys to Soil Taxonomy

Subgroup	Particle Size Class	Mineralogy Class	Activity	Temperature Regime Class	Other	Phase	Soil No
Salidic Haplocalcids	Sandy	Carbonatic		Hyperthermic		Salidic	AD101
Typic Haplocalcids	Sandy	Carbonatic		Hyperthermic		Lithic	AD102
Typic Haplocalcids	Sandy	Mixed		Hyperthermic			AD103
Salidic Haplocalcids	Sandy	Mixed		Hyperthermic		Lithic	AD104
Typic Torriorthents	Sandy-skeletal	Mixed		Hyperthermic			AD105
Typic Petrocalcids	Sandy	Carbonatic		Hyperthermic	Shallow		AD106
Typic Haplogypsids	Sandy	Mixed		Hyperthermic		Salidic	AD107
Salidic Calcigypsids	Sandy	Mixed		Hyperthermic		Lithic	AD108
Typic Calcigypsids	Sandy	Mixed		Hyperthermic		Petrogypsic	AD109
Gypsic Haplosalids	Sandy	Gypsic		Hyperthermic			AD110
Leptic Haplogypsids	Sandy	Gypsic		Hyperthermic		Lithic	AD111
Leptic Haplogypsids	Sandy	Mixed		Hyperthermic			AD112
Leptic Haplogypsids	Sandy	Mixed		Hyperthermic		Lithic	AD113
Leptic Haplogypsids	Sandy	Mixed		Hyperthermic		Petrogypsic	AD114
Salidic Leptic Haplogypsids	Sandy	Mixed		Hyperthermic			AD115
Gypsic Lithic Haplosalids	Sandy	Gypsic		Hyperthermic			AD116
Salidic Haplogypsids	Sandy	Gypsic		Hyperthermic			AD117
Salidic Haplogypsids	Sandy	Gypsic		Hyperthermic		Petrogypsic	AD118
Salidic CalcicPetrogypsids	Sandy	Mixed		Hyperthermic			AD119
Typic Petrogypsids	Sandy	Gypsic		Hyperthermic	Shallow		AD120
Typic Petrogypsids	Sandy	Gypsic		Hyperthermic			AD121
Salidic Petrogypsids	Sandy	Gypsic		Hyperthermic			AD122
Typic Petrogypsids	Sandy	Gypsic		Hyperthermic			AD123
Typic Petrogypsids	Sandy	Mixed		Hyperthermic	Shallow		AD124
Anhydritic Aquisalids	Fine	Anhydritic		Hyperthermic			AD125
Gypsic Aquisalids	Sandy	Gypsic		Hyperthermic			AD126

(continued)

Table 7.1 (continued)

Subgroup	Particle Size Class	Mineralogy Class	Activity	Temperature Regime Class	Other	Phase	Soil No
Gypsic Aquisalids	Sandy	Mixed		Hyperthermic			AD127
Typic Aquisalids	Sandy	Carbonatic		Hyperthermic			AD128
Typic Aquisalids	Sandy	Mixed		Hyperthermic			AD129
Typic Aquisalids	Sandy	Mixed		Hyperthermic		Lithic	AD130
Gypsic Haplosalids	Sandy	Mixed		Hyperthermic			AD131
Gypsic Haplosalids	Coarse-loamy	Mixed	Active	Hyperthermic		Lithic	AD132
Gypsic Lithic Haplosalids	Loamy	Mixed	Superactive	Hyperthermic			AD133
Gypsic Haplosalids	Sandy	Gypsic		Hyperthermic		Aquic	AD134
Gypsic Haplosalids	Sandy	Mixed		Hyperthermic			AD135
Gypsic Haplosalids	Sandy	Mixed		Hyperthermic		Aquic	AD136
Gypsic Haplosalids	Sandy	Carbonatic		Hyperthermic		Lithic	AD137
Petrogypsic Haplosalids	Coarse-loamy	Gypsic		Hyperthermic			AD138
Petrogypsic Haplosalids	Loamy	Gypsic		Hyperthermic	Shallow		AD139
Petrogypsic Haplosalids	Loamy	Mixed		Hyperthermic	Shallow		AD140
Petrogypsic Haplosalids	Sandy	Gypsic		Hyperthermic			AD141
Petrogypsic Haplosalids	Sandy	Gypsic		Hyperthermic	Shallow		AD142
Petrogypsic Aquisalids	Sandy	Mixed		Hyperthermic			AD143
Petrogypsic Haplosalids	Sandy	Mixed		Hyperthermic	Shallow		AD144
Typic Haplosalids	Coarse-loamy	Mixed	Subactive	Hyperthermic			AD145
Typic Haplosalids	Sandy	Carbonatic		Hyperthermic		Aquic	AD146
Typic Haplosalids	Sandy	Mixed		Hyperthermic		Aquic	AD147

Typic Haplosalids	Sandy	Mixed	Hyperthermic	Lithic	AD148
Lithic Haplosalids	Sandy	Mixed	Hyperthermic		AD149
Lithic Torriorthents	Sandy-skeletal	Mixed	Hyperthermic		AD150
Typic Torriorthents	Sandy-skeletal	Mixed	Hyperthermic		AD151
Lithic Torripsamments		Carbonatic	Hyperthermic		AD152
Lithic Haplocalcids	Sandy	Mixed	Hyperthermic		AD153
Salidic Torripsamments		Carbonatic	Hyperthermic	Petrogypsic	AD154
Typic Torripsamments		Carbonatic	Hyperthermic	Calcic	AD155
Sodic Haplocalcids	Sandy	Carbonatic	Hyperthermic	Lithic	AD156
Salidic Torripsamments		Gypsic	Hyperthermic	Shelly	AD157
Typic Torripsamments		Mixed	Hyperthermic		AD158
Salidic Torripsamments		Mixed	Hyperthermic	Calcic	AD159
Salidic Torripsamments		Mixed	Hyperthermic	Lithic	AD160
Typic Torripsamments		Mixed	Hyperthermic	Petrocalcic	AD161
Salidic Haplocalcids	Sandy	Mixed	Hyperthermic	Petrogypsic	AD162

Table 7.2 Soil families of the soil survey of Dubai Emirate correlated to UAE Keys to Soil Taxonomy

Subgroup	Particle Size Class	Mineralogy Class	Temperature Regime Class	Other	Soil No[a]
Sodic Torripsamments		Carbonatic	Hyperthermic		DE1
Oxyaquic Torripsamments		Carbonatic	Hyperthermic		DE2
Oxyaquic Torripsamments		Carbonatic	Hyperthermic	Salidic	DE3
Salidic Torripsamments		Carbonatic	Hyperthermic		DE4
Typic Toripsamments		Carbonatic	Hyperthermic		DE5
Salidic Psammaquents		Carbonatic	Hyperthermic		DE6
Sodic Torriorthents	Sandy-skeletal	Mixed	Hyperthermic		DE7
Sodic Torriorthents	Sandy-skeletal	Carbonatic	Hyperthermic		DE8
Sodic Torriorthents	Loamy-skeletal	Mixed	Hyperthermic		DE9
Salidic Torriorthents	Sandy-skeletal	Mixed	Hyperthermic		DE10
Salidic Torriorthents	Sandy-skeletal	Carbonatic	Hyperthermic		DE11
Salidic Torriorthents	Loamy-skeletal	Mixed	Hyperthermic		DE12
Lithic Torriorthents	Loamy-skeletal	Mixed	Hyperthermic		DE13
Lithic Torriorthents	Sandy-skeletal	Mixed	Hyperthermic		DE14
Typic Torriorthents	Loamy-skeletal	Mixed	Hyperthermic		DE15
Typic Torriorthents	Sandy-skeletal	Mixed	Hyperthermic		DE16
Typic Aquisalids	Fine-loamy	Carbonatic	Hyperthermic		DE17
Fluventic Haplocambids	Loamy-skeletal	Mixed	Hyperthermic		DE18
Typic Haplocambids	Loamy-skeletal	Mixed	Hyperthermic		DE19

[a] Soil families are derived from Soil Series of Dubai Emirate Soil Survey

Table 7.3 Soil series and soil classification of the intensive soil survey of Abu Dhabi Emirate correlated to UAE Keys to Soil Taxonomy

Soil Series	Subgroup	Particle Size Class	Mineralogy Class	Cation Exchange Activity Class	Temperature Regime Class	Other	Phase	Soil No
Sha'bbiyat	Lithic Haplocalcids	Sandy	Mixed		Hyperthermic			AD201
Markiya	Lithic Calcigypsids	Loamy	Carbonatic		Hyperthermic			AD202
Riqayyib	Salidic Lithic Haplocalcids	Loamy	Mixed	Superactive	Hyperthermic			AD203
Ghadar	Typic Haplocalcids	Sandy	Carbonatic		Hyperthermic		Lithic	AD204
Al Mayann	Typic Haplocalcids		Mixed		Hyperthermic			AD205
Al Babah	Typic Haplocalcids	Coarse-loamy	Mixed	Superactive	Hyperthermic			AD206
Tarbush	Lithic Calcigypsids	Sandy	Mixed		Hyperthermic			AD207
Saruk Kufa	Typic Calcigypsids	Sandy	Mixed		Hyperthermic		Salidic	AD208
Saruk Kufa, saline phase	Salidic Calcigypsids	Sandy	Mixed		Hyperthermic		ECe between 3 & 10	AD209
Al Niddah	Typic Calcigypsids	Sandy	Mixed		Hyperthermic		Lithic	AD210
Ghuweifat	Leptic Haplogypsids	Sandy	Mixed		Hyperthermic		Petrogypsic	AD211
Ghuweifat, saline phase	Salidic Leptic Haplogypsids	Sandy	Mixed		Hyperthermic		Lithic between 175 & 200 cm	AD212
Jawaloodh	Leptic Haplogypsids	Sandy	Mixed		Hyperthermic		Lithic	AD213
Jawaloodh, saline phase	Salidic Leptic Haplogypsids	Sandy	Mixed		Hyperthermic		Lithic between 75 & 95 cm	AD214
Al Daghar	Lithic Haplogypsid	Sandy	Gypsic		Hyperthermic			AD215
Al Daghar, saline phase	Salidic Lithic Haplogypsids	Sandy	Gypsic		Hyperthermic			AD216
Sila	Gypsic Lithic Haplosalids	Loamy	Mixed	Superactive	Hyperthermic			AD217
Ghayathi	Typic Haplogypsids	Sandy	Mixed		Hyperthermic			AD218

(continued)

Table 7.3 (continued)

Soil Series	Subgroup	Particle Size Class	Mineralogy Class	Cation Exchange Activity Class	Temperature Regime Class	Other	Phase	Soil No
Ghayathi, saline phase	Salidic Haplogypsids	Sandy	Gypsic		Hyperthermic			AD219
Maydur	Salidic Haplogypsids	Sandy	Mixed		Hyperthermic		Lithic between 50 & 100 cm	AD220
Al Khabar	Calcic Petrogypsids	Sandy	Mixed		Hyperthermic		Salidic	AD221
Salabik	Typic Petrogypsids	Sandy	Gypsic		Hyperthermic	Shallow		AD222
Salabik, saline phase	Salidic Petrogypsids	Sandy	Gypsic		Hyperthermic	Shallow		AD223
Barakah	Typic Petrogypsids	Sandy	Gypsic		Hyperthermic	Shallow		AD224
Barakah, saline phase	Salidic Petrogypsids	Sandy	Mixed		Hyperthermic	Shallow		AD225
Ghutail	Typic Petrogypsids	Sandy	Mixed		Hyperthermic			AD226
Ghutail, saline phase	Salidic Petrogypsids	Sandy	Mixed		Hyperthermic			AD227
At Taf	Gypsic Aquisalids	Sandy	Mixed		Hyperthermic			AD228
Shuweihat	Typic Aquisalids	Sandy	Mixed		Hyperthermic			AD229
Ruwais	Calcic Lithic Haplosalids	Loamy	Mixed	Subactive	Hyperthermic			AD230
Al Ashtan	Gypsic Lithic Haplosalids	Sandy	Mixed		Hyperthermic			AD231
Bida Hazza'a	Salidic Calcigypsids	Sandy	Mixed		Hyperthermic		ECe 10 or more	AD232
Al Uquayiah	Gypsic Haplosalids	Sandy	Gypsic		Hyperthermic		Lithic	AD233

Baynunah	Gypsic Lithic Haplosalids	Loamy	Mixed	Superactive	Hyperthermic		AD234
Al Hamra	Petrogypsic Lithic Haplosalids	Sandy	Mixed		Hyperthermic		AD235
Tarif	Petrogypsic Haplosalids	Sandy	Mixed		Hyperthermic		AD236
Harmiya	Typic Haplosalids	Sandy	Mixed		Hyperthermic		AD237
Khaberah	Typic Haplosalids	Sandy	Mixed		Hyperthermic	Lithic between 65 & 95 cm	AD238
Al Abyad	Lithic Haplosalids	Loamy	Mixed	Active	Hyperthermic		AD239
Al Usb	Salidic Lithic Torriorthents	Sandy-skeletal	Mixed		Hyperthermic		AD240
Musharib	Salidic Torriorthents	Sandy-skeletal	Carbonatic		Hyperthermic		AD241
Al Ain	Typic Torriorthents	Sandy-skeletal	Mixed		Hyperthermic		AD242
Al Hiwah	Lithic Torripsamments		Mixed		Hyperthermic		AD243
Al Hiwah, saline phase	Salidic Lithic Torripsamments		Mixed		Hyperthermic		AD244
Madinat Zayed	Typic Torripsamments		Mixed		Hyperthermic		AD245
Madinat Zayed, saline phase	Salidic Torripsamments		Mixed		Hyperthermic		AD246
Al Zafrah	Typic Haplosalids	Sandy	Mixed		Hyperthermic	Lithic between 100 &130 cm	AD247

Table 7.4 Soil series and soil classification of soil survey of the Northern Emirates correlated to UAE Keys to Soil Taxonomy

Soil Series	Subgroup	Particle Size Class	Mineralogy Class	Cation Exchange Activity Class	Temperature Regime Class	Other	Phase (Differentiating Criteria)	Soil No
Shibekah	Salidic Torriortents	Sandy	Carbonatic		Hyperthermic	Aquic-shelly		NE001
Fujairah	Typic Torriorthents	Fragmental	Mixed		Hyperthermic			NE002
Al Ain	Typic Torriorthents	Sandy-skeletal	Mixed		Hyperthermic		ESP <15; cobles/ stones < 15%	NE003
Bih	Typic Torriorthents	Sandy-skeletal	Mixed		Hyperthermic		Cobles/stones ≥15%	NE004
Miliha	Salidic Torriortents	Sandy-skeletal	Mixed		Hyperthermic		ESP ≥15; cobles/ stones < 15%	NE005
As Sirer	Typic Torriorthents	Sandy	Mixed		Hyperthermic		< 35% gravels within 100cm	NE006
Kuderah	Typic Torriorthents	Sandy	Mixed		Hyperthermic		≥ 35% gravels within 100cm	NE007
Ar Riwedah	Typic Torriorthents	Coarse-loamy	Carbonatic		Hyperthermic		>1/2 PSCS[1] is finer than VFS	NE008
Ajman	Typic Torriorthents	Coarse-loamy	Carbonatic		Hyperthermic		PSCS[1] is dominated by VFS	NE009
Al Aswad	Typic Torriorthents	Coarse-loamy	Carbonatic		Hyperthermic		Human transported material	NE010
Sharjah	Typic Torripsamments		Carbonatic		Hyperthermic		25-49% of total sand is VFS	NE011
Al Murrah	Typic Torripsamments		Carbonatic		Hyperthermic		< 25% of total sand is VFS	NE012
Digdaga	Sodic Haplocalcids	Coarse-loamy	Carbonatic		Hyperthermic			NE013
Al Dhaid	Typic Haplocalcids	Sandy-skeletal	Mixed		Hyperthermic		Total silt + clay <15%	NE014

Al Kabkub	Typic Haplocalcids	Sandy-skeletal	Mixed		Hyperthermic		Total silt + clay ≥ 15%	NE015
Al Maalla	Typic Haplocalcids	Sandy	Mixed		Hyperthermic			NE016
Al Kihef	Typic Haplocalcids	Sandy	Carbonatic		Hyperthermic			NE017
Khatt	Sodic Haplocambids	Coarse-loamy	Mixed	Active	Hyperthermic			NE018
Ras Al Khaimah	Typic Haplocambids	Coarse-silty	Carbonatic		Hyperthermic			NE019
As Sihebi	Typic Haplocambids	Sandy over loamy	Carbonatic		Hyperthermic			NE020
Wahala	Leptic Haplogypsids	Coarse-loamy over sandy or sandy skeletal	Gypsic over carbonatic		Hyperthermic			NE021
Al Yafar	Typic Haplogypsids	Loamy-skeletal	Mixed	Superactive	Hyperthermic			NE022
Al Madam	Typic Calcigypsids	Coarse-loamy	Carbonatic		Hyperthermic			NE023
Ar Ramlah	Typic Aquisalids	Sandy	Carbonatic		Hyperthermic			NE024
Um Al Quwain	Gypsic Aquisalids	Fine-gypseous over loamy	Hypergypsic over carbonatic		Hyperthermic			NE025
Ar Rafah	Lithic Aquisalids	Sandy	Carbonatic		Hyperthermic			NE026
Hisan	Gypsic Haplosalids	Sandy	Carbonatic		Hyperthermic	Aquic		NE027
Misekhin	Gypsic Haplosalids	Coarse-silty	Gypsic		Hyperthermic			NE028

Differentiating criteria are provided only where there is more than one series in a given family

[1] *PSCS* particle size control section, *VFS* very fine sand, *ESP* exchangeable sodium percentage

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