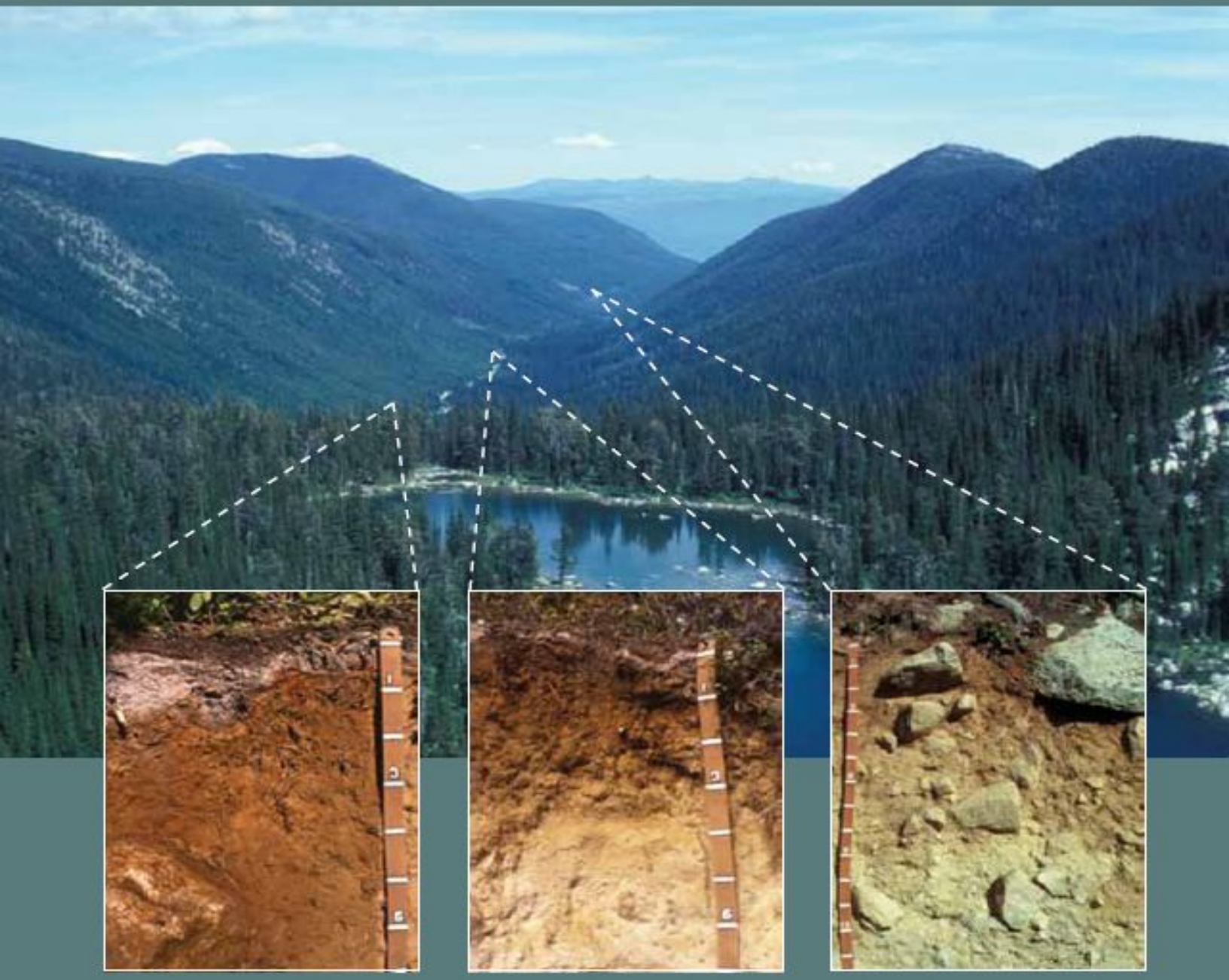
SOIL GENESIS AND CLASSIFICATION

sixth edition



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WILEY-BLACKWELL

Contents

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WILEY-BLACKWELL
A John Wiley & Sons, Ltd., Publication

This edition first published 2011

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical and Medical business with Blackwell Publishing.

Registered Office
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PO19 8SQ, UK

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Library of Congress Cataloging-in-Publication Data

Soil genesis and classification / S.W. Buol ... [et al.]. – 6th ed.
p. cm.
Includes bibliographical references and index.

ISBN-13: 978-0-8138-0769-0 (hardcover : alk. paper)
ISBN-10: 0-8138-0769-7
1. Soil science. 2. Soil formation. 3. Soils–Classification. I. Buol, S. W.
S591.B887 2011
631.4–dc22

2011012321

A catalogue record for this book is available from the British Library.

This book is published in the following electronic formats: ePDF 9780470960592; Wiley Online Library 9780470960622; ePub 9780470960608; Mobi 9780470960615

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Preface to the First Edition

We have intended in this work to summarize the body of knowledge called pedology, to direct readers to sources of additional information in the literature, and to encourage students to learn directly from the soil in its natural setting. This book is one in a succession of periodic reviews of soil morphology, genesis, and classification that may serve as stepping stones across the seeming morass of terminology and information.

These are exciting times in pedology. The “information explosion” in the several fields of soil science has enabled us to better understand soils and define them more quantitatively. The adoption and use of the Comprehensive Soil Classification System has provided new concepts and nomenclature. And the uses of soil survey, the end product of our classification, have greatly increased through their interpretation for application to land use and productivity studies, especially for nonfarm land use problems.

Yet the student, formally enrolled in college or a self-taught learner, has not had access to any summary in the form of an up-to-date reference or text. We have designed this book with the hope and desire that it will be equally useful to graduates and advanced undergraduates, professional pedologists and geographers, ecologists, and all others interested in or involved with the land. Portions of this book we hope and expect will be of use to planners, to highway engineers, and to sanitarians involved with disposal problems. An understanding of soil genesis and classification is a prerequisite to sound land use planning and land management. Soil science can help people learn to live adequately and significantly in a varied ecosystem and derive necessities from it without damaging it.

Limited use has been made of sketches to illustrate soil profiles. It is our intent that these be supplemented by color

slides to illustrate classroom lectures. The Marbut memorial collection of 2-by-2-inch color slides assembled by the Soil Science Society of America is excellent for this purpose.

Our effort is in appreciation of the direction and motivation of which we have been the fortunate recipients in the past and an attempt to share what we have learned. We are grateful to the many persons who helped us in preparing this manuscript. The responsibility for any oversights is ours.

Madison, Wis., 1973

S. W. Buol
F. D. Hole
R. J. McCracken

Preface to the Second Edition

The second edition has entailed considerable revision that includes updating those portions that deal with Soil Taxonomy, which had not been formally published at the time of preparation of the first edition. We have also updated the soil classification systems of other countries and of FAO according to revisions and additions that have been made since the early 1970s. Chapters 25 and 26 have been completely rewritten, consistent with what we believe to be desirable trends in considering soils in three dimensions (as soilscapes) and in increasing interpretation of soil maps and scientific comprehensive soil classification systems for many specific technical applications. The recent publication of *Minerals in Soil Environments* by the Soil Science Society of America (J. B. Dixon and S. B. Weed, eds.) has greatly added accessibility to soil mineralogical literature. The experiences of the authors since 1973, as well as comments from students and other readers, have led to the removal of some ambiguous and erroneous statements and to the addition of some new material in most of the chapters.

Madison, Wis., 1978

S. W. Buol
F. D. Hole
R. J. McCracken

Preface to the Third Edition

The third edition reflects an update of literature and experience during the past seven years. More than that, it attempts to reflect the "coming of age" of *Soil Taxonomy* as a major unifying force in promoting worldwide communication and understanding of soil morphology, genesis, and classification. Since our preparation of the second edition, considerable effort and progress have occurred in bringing global experience to *Soil Taxonomy* through the formation of international soil classification committees and through the publication of many papers and symposia. The efforts of these committees resulted in major changes with minimum violence to the system. Because of the official recommendations of the international committees, we feel that *Soil Taxonomy* has now accomplished the most difficult of its objectives, namely, that "the taxonomy should be capable of modification to fit new knowledge with a minimum of disturbance" (Soil Survey Staff 1975, p. 8). Great progress has also been made toward another of its goals that "the taxonomy should provide for all soils that are known, wherever they may be" (Soil Survey Staff 1975, p. 8). Therefore, in this edition we have attempted to adhere more closely to terminology and provisions of *Soil Taxonomy*, updating the terminology of older literature where necessary and stressing more recent research results. We have included discussions of approved amendments to *Soil Taxonomy*, such as the Kandi great groups, as well as pending proposals for major changes in the classification of Oxisols and the proposed Andisol order.

We are mindful, and stress to our readers, that classification should neither bias nor limit investigations concerning soils. Students should be encouraged to challenge the "wisdom of the past" that is the basis of any classification. In soil genesis, it is often said that the experiments have been conducted. Thus, the soil scientist is

left to observe the result and interpret the processes by which the pedologic transformations have taken place. As such, the systematic and orderly observation of soil in the field, with the assistance of analytical techniques on samples brought back to the laboratory and greenhouse, remains the basis for future advances in soil science.

In this third edition, we have updated our review of soil classification systems used in other countries so readers may fully appreciate how soils are viewed and classified around the world.

We also have added new material reflecting the advances in soil genesis (that we have brought into chapters on flux factors and site factors) and in soil cover (including soils and landscapes and spatial variability). And the new developments and approaches in soil survey interpretation are reflected in a revised and expanded chapter on that subject.

1988

S. W. Buol
F. D. Hole
R. J. McCracken

Preface to the Fourth Edition

This fourth edition reflects advances in concepts and new information based on research and field experience. It also describes the many changes in soil classification reflected in *Soil Taxonomy* in the six years since the third edition was prepared and distributed. This edition reflects several changes in terminology, advances in technology, and our increased understanding of soil formation processes.

We draw attention to the reorientation and expansion of the range and scope of coverage in soil genesis and classification. This includes additional emphasis on the biogeochemistry of soil systems and the roles of soils in ecosystems.

This edition includes for the first time a definition and description of soils in the coldest regions of the planet that are actively being considered as a new order, Gelisols, in *Soil Taxonomy*. Also, in this edition you will find more information about the genesis, properties, and classification of soils frequently present in tropical and subtropical regions and soils with andic soil properties, the Andisols.

Also included are discussions and explanations of the use and applications of new technology via soil databases, soil geographic information systems, ground penetrating radar, increased use of aerial photography for soil studies, and new approaches to modeling soil systems. We also discuss the growing problem of trying to characterize and adjust for spatial variability within soil mapping units. Also included in this edition are discussions of concerns about soil quality, measures for remediation of soil problems such as waste disposal, and soil loss by erosion. Certain chapters of the previous editions have been combined and blended to produce a more comprehensive and cohesive picture and description of soil systems.

Another plus is the addition of a fourth author who is actively teaching and conducting research in arid and semiarid areas as well as internationally.

1997

S. W. Buol
F. D. Hole
R. J. McCracken
R. J. Southard

Preface to the Fifth Edition

This fifth edition presents the current understanding of soil as a thin layer of the earth's surface that forms an interface between the inorganic minerals of the earth's crust and the organic components of biologic entities living on the land and in the surrounding atmosphere.

Soil genesis, or the more encompassing concept of pedology, is an evolving discipline devoted to understanding how soils differ in form and function. The widely held view that a soil is a formed and therefore a nearly stable entity has evolved into the view that soil is a dynamic natural entity that interfaces with ecosystems and human endeavors. Chemical, biological, and physical reactions are constantly taking place within soil. Some of these reactions produce changes so slowly that human time scales are inadequate for measuring and comprehending soil dynamics. Other changes are rapid, episodic events that are viewed by humans as catastrophic and that challenge soil scientists to devise techniques to quantify the magnitude and probability of their occurrence.

Human efforts to understand and communicate knowledge about soils are reflected in attempts to classify soils. This edition reviews a spectrum of soil classification systems and presents the culmination of more than two decades of testing and revisions in the most detailed and comprehensive system for soil classification as reflected in the 1999 publication of the second edition of *Soil Taxonomy*. To better reflect the state of knowledge, new nomenclature has been added and improvements have been made in the systematic structure of soil classification categories. New analytical techniques have been utilized to more quantitatively identify soil properties and define class limits.

While we accept that soil changes, as external energy from the sun and rain is dissipated on its mineral

components and as new organic components are added from the biological organisms that invade, we have to accept that humans also change. Just as in soil, where new components are formed to replace weathered components, new authors have replaced some of the stalwart authors of earlier editions.

2003

S. W. Buol
R. J. Southard
R. C. Graham
P. A. McDaniel

Preface to the Sixth Edition

This sixth edition presents current concepts of how soils are formed and sustained as an entity on the surface of the land masses on planet earth. Soil is an entity composed of mineral material inherited from geologic rock as altered by the actions of water and additions of organic materials injected by the plants and animals that find root within and tread on its surface. In response to the multitude of geologic materials, climatic conditions, and biologic ecosystems that presently exist and existed in the past, soils have acquired a multitude of properties that defy attempts to characterize soil as a singular entity. Thus, we speak of soils of the earth.

Human efforts to better understand soil properties and behavior and to more efficiently utilize soils for human endeavors have resulted in numerous attempts to classify the various kinds of soil. This is a never-ending endeavor that proceeds as new chemical, physical and biological methods are developed to analyze soil material. There is also the realization that soils have daily and seasonal dynamic features of temperature and moisture that affect human usage. All of these have to be considered and addressed in the search for more comprehensive understanding of the role soils play in ecosystem function, and how humans can best utilize and conserve the various kinds of soil.

This edition builds on the material contained in earlier editions and incorporates more detailed data regarding specific examples of how soils acquire various characteristics. We include a section of color plates that help readers better visualize the various kinds of soil. Also included is the recent recognition that soils periodically covered by shallow water are an important component of the spatial association between land and sea. We have expanded on methods of communicating and analyzing spatial information that have been greatly enhanced by

modern electronic technologies. These technologies enable the rapid dissemination of information among soil scientists and users of soil information, and drive the development of new methods for modeling processes of soil formation and resulting patterns of soils on the landscape.

Our knowledge of the soils in the world is ever increasing as we utilize new analytical methods to investigate soil chemical, physical, and biological properties from the nano to the landscape scale and modern methods of transportation to gain access to previously little-studied areas of the world. This has greatly expanded not only our understanding of how soils are formed but also the techniques different human cultures utilize to manage the various kinds of soil from which they obtain human nourishment.

It is through the amalgamation of a multitude of individual observations as reported in scientific publications that this edition has been assembled.

S. W. Buol
R. J. Southard
R. C. Graham
P. A. McDaniel

SOIL GENESIS AND CLASSIFICATION SIXTH EDITION

1

Introduction

This book discusses the composition of soils as natural bodies resulting from biogeochemical processes on the land surfaces of earth. It also examines human attempts to better understand the interaction of soils with biological components of the ecosystem, including humans, via the study and classification of soils. The main themes of soil genesis and classification follow:

1. Identification and description of soil profiles and pedons (soil morphology);
2. Characterization of chemical, mineralogical, and physical soil properties aided by laboratory and field investigations of soil properties;
3. Categorization and classification of soils according to similarity of properties and function;
4. Mapping the spatial distribution of soils as they exist on the earth's surface;
5. Analyses of the relationships between soil properties and the many potential uses of soils.

All of these activities comprise a recognized area of specialization within the discipline of soil science. The Soil Science Society of America changed the name of its Soil Genesis, Morphology, and Classification division to Pedology about a decade ago (Simonson 1999). "Pedology" (from Gr. *Pedos*, "ground," and *logos*, "science"; original formed as Russian, *pedologiya*) is a collective term used to refer to the combination of the two phases of soil science: (1) soil genesis and classification and (2) more inclusively, also soil morphology, survey or mapping, and interpretations.

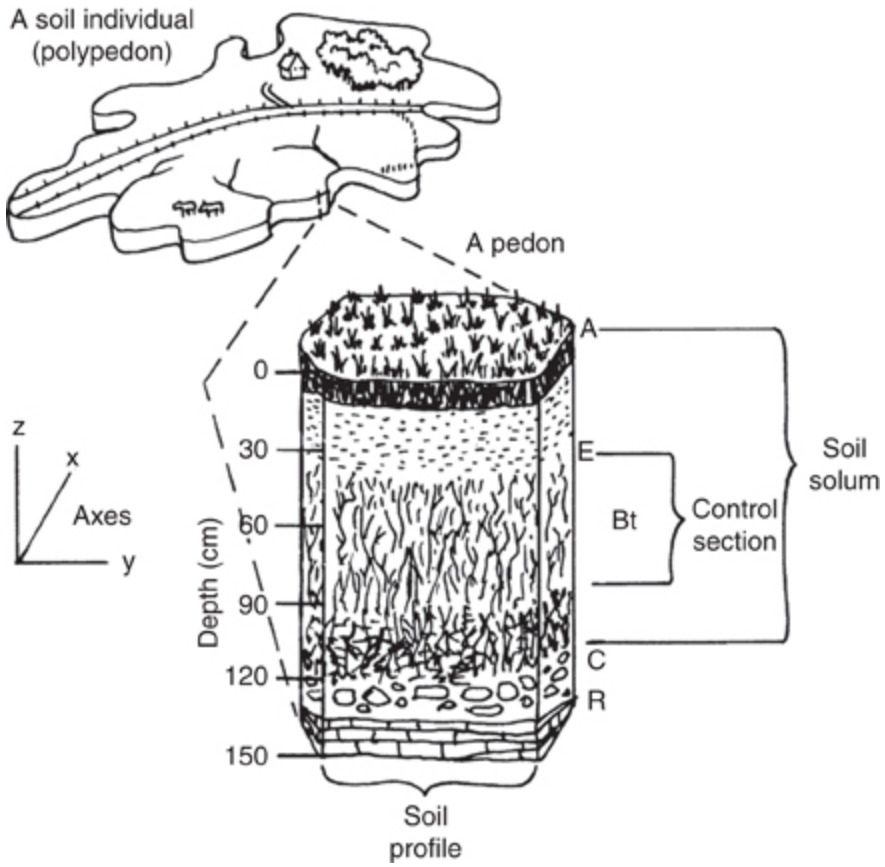
Pedology is practiced in many other countries, especially European and Asian countries and Australia (Editorial Staff 1940; Gibbs 1955; Leeper 1953, 1955; Northcote 1954). The International Union of Soil Sciences includes these aspects of soil science primarily in their commission of Soil in Space and Time.

Subdivisions of Pedology

Following are descriptions of each of the distinctive phases of activity encompassed by pedology.

Soil genesis is a century-old science that has dealt with soil in three conceptual phases: (1) as a geologic entity, (2) as a product of factors and processes of soil formation, and (3) as an open system capable of supporting the functions of soil in all ecosystems. Soil genesis includes concepts of biogeochemistry. It conceptualizes the factors and processes responsible for the chemical, physical, and mineralogical properties of all soils and the spatial distribution of various kinds of soil on the landscape.

Figure 1.1. A soil individual is a natural unit in the landscape, characterized by position, size, slope, profile, and other features.



Soil classification is the categorization of soils into groups at varying levels of generalization according to their physical, mineralogical, and chemical properties. The objectives of soil classification include organization of knowledge, ease in remembering properties, clearer understanding of relationships, and ease of technology transfer and communication.

Many classification systems are used to classify soils and soil materials. Some are designed to relate soil properties to specific uses and are referred to as “technical classification systems.” Others, termed “natural classification systems,” are structured to categorize all soil properties. The primary classification system used in this book is *Soil Taxonomy*, a natural classification system. When the term *Soil Taxonomy* is capitalized and italicized in this book, it refers to the system of classification developed by the U.S. Department of Agriculture (USDA) Soil Survey Staff with the support of