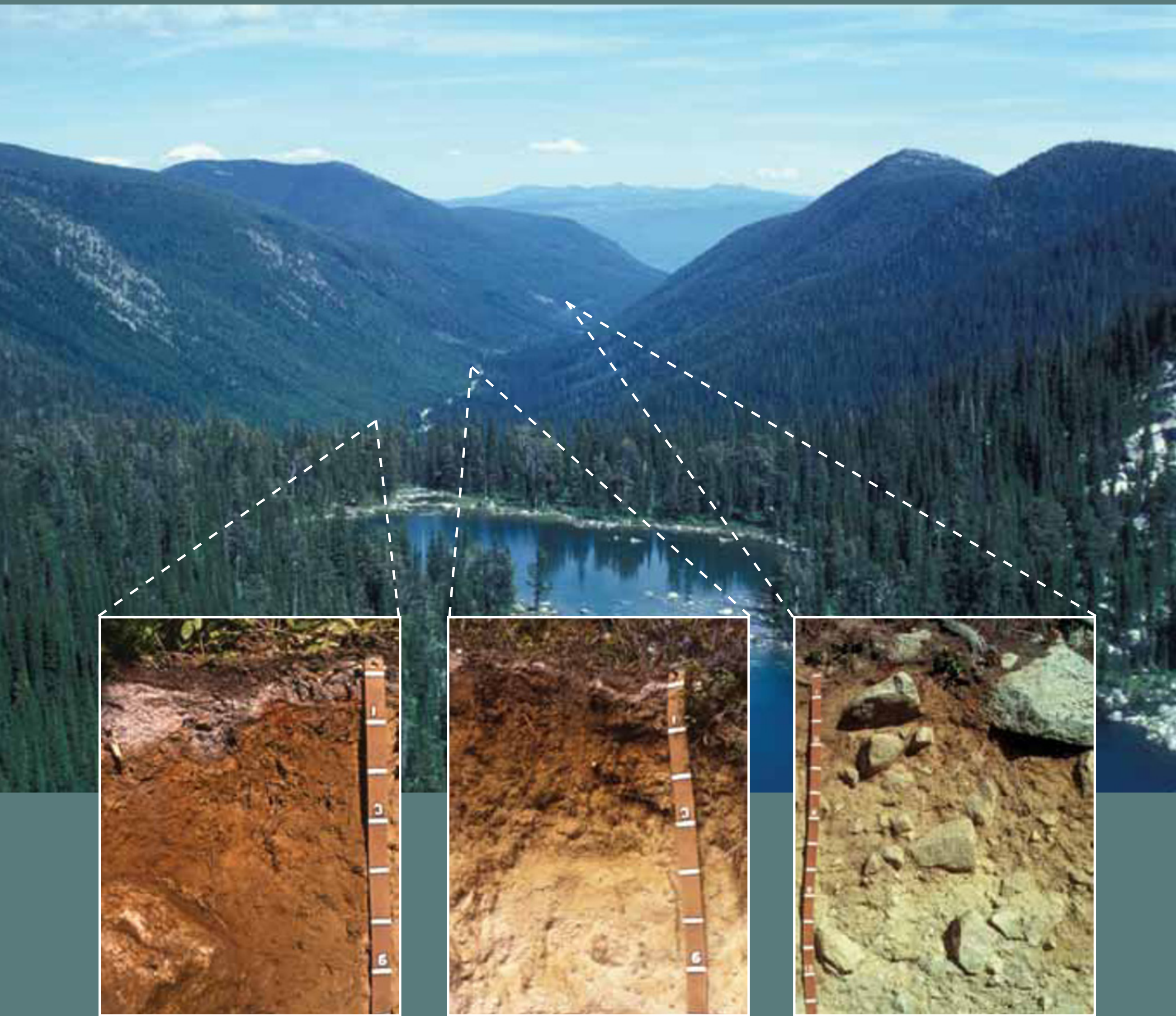
# SOIL GENESIS AND CLASSIFICATION

## sixth edition



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

WILEY-BLACKWELL

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SIXTH EDITION

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S. W. BUOL
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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<br>
F. D. Hole<br>
R. J. McCracken<br>
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

# Introduction

# 1

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

*Soil Genesis and Classification*, Sixth Edition. S. W. Buol, R. J. Southard, R. C. Graham and P. A. McDaniel.

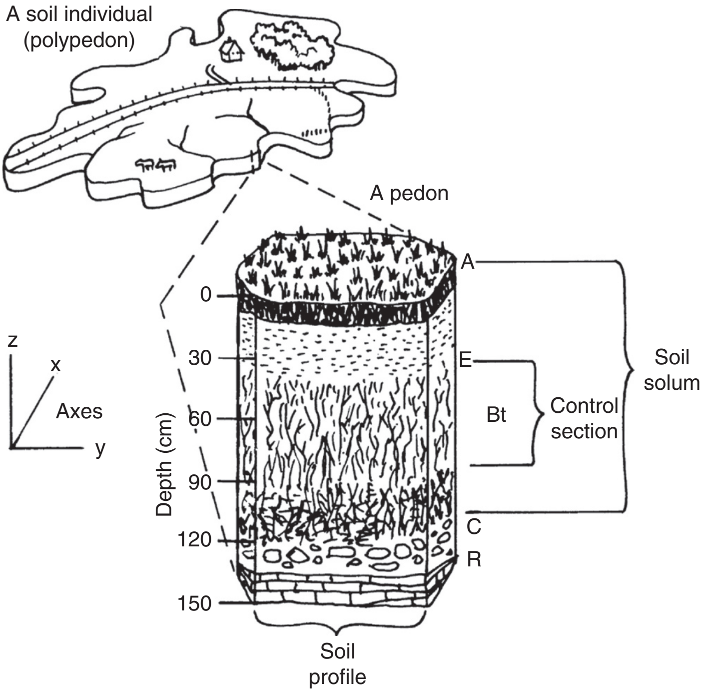


**Figure 1.1.** A soil individual is a natural unit in the landscape, characterized by position, size, slope, profile, and other features.

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.

*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 and contributions from land-grant universities, other federal and state resource agencies participating in the National Cooperative Soil Survey, and colleagues from other countries. It was formally released and published by the USDA in 1975, and a second edition was published in 1999 (Soil Survey Staff 1975, 1999). The system is also updated periodically through the release of revised *Keys to Soil Taxonomy*. The most recent edition of the *Keys* was published as the 11th edition (Soil Survey Staff 2010). *Soil Taxonomy* is now widely used throughout the world. *Soil Taxonomy* uses quantitative morphological criteria to define kinds of soil and concepts of soil genesis to guide the selection and orderly application of these criteria.

All classification systems are a mirror or state-of-the-art indicator of the available knowledge about the objects classified, assembled in a systematic fashion to facilitate communication with other scientists and, most importantly, with the students who will become the future scientists. The fact that classifications systems change over time is an inevitable result of research in soil science and in other sciences that relate to uses of the soil.

*Soil morphology* encompasses the color, physical structure, chemical and mineralogical properties of soil material; the spatial association of materials in soil horizons (Figure 1.1); and the temperature and moisture dynamics of soil in situ. The thickness, vertical relationship, number, and three-dimensional ranges and variations of horizons found in the smallest recognizable volume of soil that is classified (called the "pedon," the word rhymes with "head-on") are described and recorded by a standard nomenclature outlined in Chapter 2.

## Perspective on the Role of Soil Genesis and Classification

It is useful, important, and interesting to consider how the study of soil genesis and classification interacts with other fields of soil science and other scientific disciplines. This is especially true for technical soil classifications derived from scientifically based natural classifications systems like *Soil Taxonomy* (Buol and Denton 1984). Soil properties are primary reagents in field experimentation. Documentation of soil properties at research sites is essential for the successful transfer of research results to other locations.

Soil genesis and classification studies have made contributions to research design and data acquisition in other fields of soil science, including biogeochemical redistribution of nutrients in ecological systems, ecology of soil microbes and mycorrhizae, and the availability and distribution of plant essential nutrients such as phosphorus and nitrogen in different types of soils (Runge and McCracken 1984). Soil maps furnish basic inputs to soil conservation planning in the United States and provide information used in equations for predicting soil loss and water pollution potential under various management practices on different soils.

Characterization of soil properties is fundamental to all soil studies. Complete soil characterization for classification purposes requires that all horizons of the soil be analyzed. Many laboratory and greenhouse studies require only characterization of soil material from a few horizons, but practical application of the results obtained from such studies requires verification with field studies. Soil characterization methods draws heavily on methods of soil chemistry, physics, mineralogy, microbiology, and biochemistry. Conversely, methods and results initially obtained in soil characterization and soil genesis studies have been useful in perfecting methods of soil analysis by providing materials representative of all kinds of soil for analysis.

Soil genesis embraces the concept of soil as "a natural entity to be studied as a thing complete in itself" (Cline 1961). This concept has survived the fragmentation of soil science into the subdisciplines of soil chemistry, soil physics, soil microbiology, soil fertility, and soil management by drawing upon and integrating the concepts, theories, and facts of these subfields of soil science into a holistic, integrated, multidisciplinary view of soil as a natural entity. Soil genesis and classification, or pedology, may also be likened to a system of bridges connecting the disciplinary islands of geology, biology, chemistry, physics, geography, climatology, agricultural sciences, economics, anthropology, and archeology. The interdisciplinary nature of this field of soil science gives it added importance in the training of scientists (Abelson 1964). Soil genesis and classification and its allied activities therefore have many interactions with and contributions to fields of science other than the science of soils.

Soil genesis and soil classification have some roots in geology, for they grew out of the study and mapping of rocks. The close ties between geology and soil science stem from the fact that most soils are derived from geologic materials such as granite, limestone, glacial drift, loess, and alluvium. Several of the early pioneer soil scientists were geologists by training. Because differences among soils are due in part to the different landforms they occupy, and because age of the soil is related to the stability of the surface on which they have formed, close ties between soil specialists in genesis and classification and geologists specializing in geomorphology continue to be strong and mutually beneficial.

Soil genesis and classification is seldom concerned with entire geological deposits, but rather deal with the upper portion of the deposit that has been influenced by plant and animal activity and by the intrusion of water and energy from the land surface. Therefore, soil genesis and classification, which deals with the dynamic, biologically active soil system, must also be concerned with biology, especially the subsciences of ecology, microbiology, plant physiology, and botany. Hans Jenny (1980) regarded soil and vegetation as coupled systems and thus an ecosystem. A knowledge and awareness of plant-soil interactions, meteorology, and hydrology are essential for soil scientists interested in soil genesis and classification.

Soil underpins human food production and is a very significant component in our total stock of natural resources. Production economists call on soil scientists for data and estimates of the productivity of various soils under defined systems of management. Natural resource economists are concerned about the amount and distribution of useful productive land. Planners at local, state, regional, and national levels use soil surveys and soil interpretations for land-use planning, environmental protection, selection of building and highway sites, tax assessment, and land evaluation (Simonson 1974; Bauer 1973; Jarvis and Mackney 1979). This places additional responsibility on soil classifiers and interpretation specialists to provide sound, scientifically based evaluations of flooding, structural instability, and other economic potentials of individual kinds of soil. Soil scientists must consider economic and resource conservation factors in the preparation of technical and natural classification systems. Archeologists and anthropologists utilize soil information and data to date construction and destruction of human settlements and explain changes in agricultural practices (Olson 1981; Harrison and Turner 1978).

It is clear from the preceding examples that soil genesis and classification interact with a large number of disciplines and interests. Not only does this signify the important and varied uses for soil information, but it also challenges those working in this area to be aware of all potential uses as they seek to better understand the dynamic role of soils in the environment.

## Developmental Stages of a Discipline

Three stages in the development of a discipline enumerated by Whitehead (1925) may be applied to soil genesis and classification and their related components:

Stage 1: Location in space and time. The basic operation of mapping soils to record their positions in space is a prerequisite to genesis and classification and their related components.

Stage 2: Classification. Whitehead (1925) calls this a "halfway house between the immediate concreteness of the individual things and the complete abstraction of mathematical notions." A great variety of genetic and descriptive soil classifications have been developed. Terminology used ranges from symbols, to synthetic terms based on classical languages, to a hodgepodge of folk terms. All classification systems rely on the knowledge and understanding available and are subject to change as that knowledge and understanding evolve.

Stage 3: Mathematical abstractions. More highly developed abstractions are possible by mathematical means. Mathematical models also help us to predict. Relationships between soils and other natural phenomena are conceived from observations. Statistical expressions are possible when sufficient quantitative data become available (Bidwell and Hole 1964; Hole and Hironaka 1960; Arkley 1976; Jenny 1941, 1961b, 1980). Computer-based models that project the effects soil properties have on numerous entities utilize both soil characterization data and spatial data recorded on soil maps (Bouma 1994). Attempts to utilize existing data to model soil genesis and classification, and to aid soil mapping have become an increasingly important part of pedologic research (Bouma and van Lanen 1987; Vereecken et al. 1992; Tietje and Tapkenhinrichs 1993; Rasmussen et al. 2005; Hartemink et al. 2008).

Developmental stages in soil classification are not chronological. Although soil mapping has identified many of the soils in the world, many areas remain poorly explored. Also, the methods for identifying soil properties are improved as new analytical technologies are developed. Classification of an object such as soil cannot be considered complete until everything is known about that object. Classification can only reflect what is known, and in soil science this knowledge base increases as new lands are explored and new analytical techniques are employed to describe and analyze soils. Mathematical abstractions are built on a foundation of what is known. Improvements can be made as more extensive and intensive databases become available.

The components of soil science to which we have been referring are subjects in this book. We think it desirable to have a brief summary of the historical development and a synopsis of the principles, concepts, and theories plus notes on the methods of each before proceeding to the specifics.

## Historical Developments in Soil Genesis

By reviewing history we gain perspective about modern soil genesis concepts, become aware that this field of science is dynamic, come to appreciate the resistance new ideas have encountered, and become aware of the newness of soil science as we know it today.

Aristotle (384–322 B.C.) and his successor Theophrastes (372–287 B.C.), considered the properties of soil in relation to plant nutrition. Roman writers who discussed differences among soils in relation to plant growth included Cato the Elder (234–149 B.C.), Varro (116–27 B.C.), Virgil (70–19 B.C.), Columella (about A.D. 45), and Pliny the Elder (A.D. 23–79). In 1840 Justus von Liebig published *Chemistry Applied to Agriculture and Physiology* in which he states that plants assimilate mineral nutrients from the soil and proposed the use of mineral fertilizers to fortify deficient soils (Liebig 1840).

In the middle of the nineteenth century several German scientists, including Ramann and Fallou, developed agrogeology, which viewed soil as weathered, somewhat leached surface mantle over rock. Fallou (1862) suggested that "pedology"—which to him signified theoretical geological soil science—be distinguished from "agrology," the practical agronomic soil science.

In Russia, Lomonosov (1711–1765) wrote and taught about soil as an evolutionary rather than a static body. In 1883, V. V. Dokuchaev (1846–1903) (Figure 1.2) published a report of a field study of Chernozem soils present under grasslands in which he applied the principles of morphology to soils, described major soil groups and their genesis, produced the first scientific classification of soils, developed methods of mapping soils, and laid the foundation for soil genesis and soil geography. In 1886, Dokuchaev proposed that "soil" be used as a scientific term to refer to "those horizons of rock that daily or nearly daily change their relationship under the joint influence of water, air, and various forms of organisms living and dead" (Vilenskii 1957). He later defined soil as an independent natural evolutionary body formed under the influence of five factors, of which he considered vegetation the most important. Russian soil scientists K. D. Glinka

**Figure 1.2.** V. V. Dokuchaev.

**Figure 1.3.** E. W. Hilgard.

(1867–1927) and S. S. Neustruyev (1874–1928) reemphasized the concept of soil as a superficial geological entity, a weathered crust that exhibits specific properties correlated with climatic zones. V. R. Williams (1863–1939), another Russian soil scientist, developed the concept of soil genesis as essentially a biologic process rather than a geologic one. He stated that soil formation takes place best in grasslands. P. E. Müller (1878) wrote a monograph on soil humus, describing the biological character of soil genesis in forests.

In the USA, E. W. Hilgard (1833–1916) (Figure 1.3), working as a geologist and soil scientist in Mississippi and California, wrote about the relationships between soils and climate (Hilgard 1892). He "saw the farmer's dirt as a richly embroidered mantle of earth, whose design and fabric were deserving of scientific zeal and quest" (Jenny 1961a). G. W. Coffey, a soil scientist with the U.S. Division of Soil Survey, published a soil classification system for the United States based on the principles of soil genesis expressed by Dokuchaev and Glinka (Coffey 1912). However, this was an idea whose time had not yet come in the United States, because the idea of soil as a superficial geologic material still dominated.

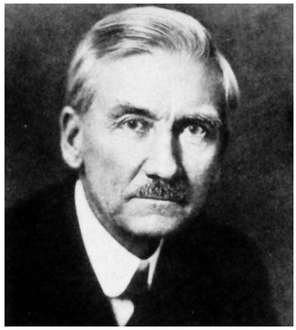

**Figure 1.4.** C. F. Marbut.

**Figure 1.5.** C. E. Kellogg.

C. F. Marbut (1863–1935) (Figure 1.4), while director of the U.S. Soil Survey Division, read Glinka's publications on soil genesis and classification and introduced their concepts into soil survey programs in the United States, as well as introduced his own emphases on the soil profile and the 'normal' soil (Krusekopf 1942).

Charles E. Kellogg (1902–1977) (Figure 1.5), Marbut's successor as director of the USDA Division of Soil Survey, continued the enhancement of the themes and principles of soil genesis as a necessary basis for soil classification and soil survey while introducing uniform techniques and nomenclature among soil scientists (Kellogg 1937; Soil Survey Staff 1951, 1960; Kellogg 1974).

Hans Jenny (1899–1992) (Figure 1.6) wrote a masterful treatise on the five factors governing the development of soils (Jenny 1941). He noted that quantitative elucidation of the processes of soil formation could not proceed without a larger body of data than was available. In a later work, Jenny (1980) put the five soil-forming factors

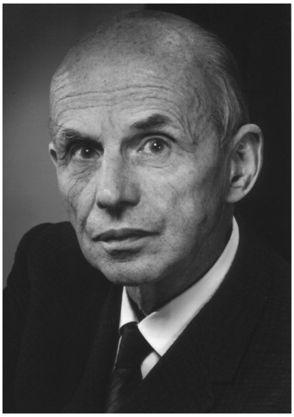

**Figure 1.6.** H. Jenny.

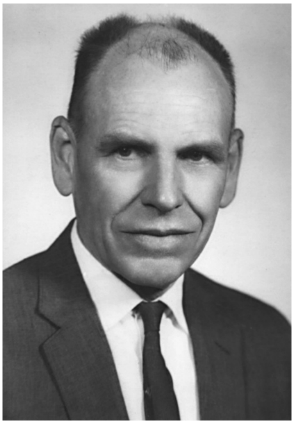

**Figure 1.7.** G. D. Smith.

"into a conceptual framework that permits solving the equation when landscape configurations are favorable."

In 1959, R. W. Simonson brought out the significant point, not well recognized previously, that many genetic processes may be simultaneously and/or sequentially active in any one soil (Simonson 1959). He pointed out that the horizons of a soil profile reflect the relative strength of these processes and the degree to which they offset each other.

In the 1960s and early 1970s, G. D. Smith (1907–1981) (Figure 1.7), as director of Soil Survey Investigations for the USDA Soil Conservation Service and chief architect of *Soil Taxonomy* (Soil Survey Staff 1975), with his colleagues, further advanced and refined soil genesis studies in support of soil classification and soil survey. Smith made the important point that concepts of soil genesis are very important for soil classification, but factors and processes of soil genesis cannot be used as the sole basis for soil classification because they can rarely be quantified or actually observed (Smith 1983). He stressed that soil classification was best based on properties that could be observed and measured within the present soil.

## Concepts of Soil Genesis

**Concept 1.** Soil-forming processes, also referred to as pedogenic processes and biogeochemical processes, that are active in soils today have been operating over time and have varying degrees of expression over space (that is, at various locations). The geologic uniformitarian principle that states "the present is the key to the past" is also applicable in soils with respect to downward translocation, biocycling, and transformation of materials—back to the time of appearance of organisms on the land surface. We can improve our elucidation of soil formation of differing soil profiles by application of this principle.

**Concept 2.** Many soil-forming (and soil-destroying) processes proceed simultaneously in a soil, and the resulting soil properties reflect the balance of both present and past processes (Simonson 1959). Soil-forming processes are actually combinations of specific reactions that are characteristic of particular time spans and conditions.

**Concept 3.** Distinctive combinations of geologic materials and processes produce distinctive soils. Observable morphological features in a soil are produced by certain combinations of pedogenic processes over time. The degree to which a morphological feature is expressed is dependent on the intensity and duration of the process.

**Concept 4.** Five external factors provide the reactants and energy to drive the pedogenic processes within the soil. These factors are climate, organisms, relief, parent material, and time.

**Concept 5.** Present day soils may carry the imprint of a combination of pedogenic processes and geologic processes not presently active at that site. Therefore, knowledge of paleoecology, glacial geology, and paleoclimatology is important for the recognition and understanding of soil genesis.

**Concept 6.** A succession of different soils may have taken place at a particular spatial location as soil-forming factors changed. The soil surface is lowered by erosion and dissolution of soil material and elevated by depositions of soil materials and tectonics. In this respect, the volume of material examined as soil on the land surface actually changes in vertical space over time.

**Concept 7.** The time scale for soil formation is much shorter than the geologic time scale and much longer than the age span of most biological species. The vulnerable position of soil as the skin of our dynamic earth subjects it to destruction and burial by episodic geologic events. Few, if any, soils are older than Tertiary and most no older than the Pleistocene epoch. Succession of vegetative communities and human activities often alter soil properties over short spans of time.