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Soil Profile Descriptions

Summary

Soil profile description forms the basis for understanding and communicating soil properties among soil scientists and other professionals. Professionals from many disciplines often prepare or use soil profile descriptions. We present a guide that will enable someone without a large amount of background knowledge or previous experience to complete very basic soil profile descriptions. The material presented for this chapter uses the U.S. system of soil taxonomy for horizon nomenclature (Soil Survey Staff, 1999, 2006), but the step-by-step soil profile description method is valid anywhere in the world.

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Although many of the technical terms used in this chapter are defined, the reader should consult the Soil Science Society of America's Online Glossary of Soil Science Terms (https://www.soils.org/sssagloss/, SSSA, 2008) for terms with which they are unfamiliar. Another online resource for soil profile descriptions is the United States Department of Agriculture–Natural Resources Conservation Service Information for Soil Scientists website (http://soils.usda.gov/scientists.html; USDA-NRCS, 2008), which provides links to many additional websites useful for geoscience professionals.

For a soil profile description to be useful, it needs specific, standardized terminology that allows a trained professional to understand the profile without having to see the soil personally. The description process begins first with a site description and second, choosing a location on the landscape representative of the site. This may require multiple profile descriptions on any given site. The level of detail of the description should reflect the projected land use. The description process begins by noting changes in properties and identifying the individual soil layers, or **horizons**. Once the horizons are identified, they are described for several properties, including the matrix color (i.e., the dominant background color), the color of redoximorphic features, texture, structure, consistence, thickness, and depth. Additional description may include roots and pH. All parameters should be described with standard terminology. The profile description ultimately should accurately represent what the describer observed in the field. Once finished, the description can be used by soil scientists and other professionals in land use planning for the site in question.

Understanding and interpreting soil properties is an iterative process that begins with a description of the soil morphology (i.e., form and organization) and leads to an assessment of the soil's suitability for its proposed land use

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(Lindbo et al., 2005). A soil profile morphological description is language that soil scientists use to communicate the properties of the soil that affect its eventual land use. A soil profile morphological description applies the soil scientist's model of soil genesis, thus providing a better understanding of how parent material influences topographic and drainage controls, stability of the soil, and possibly suitability of the overall site. The description also provides a framework of the major soil formative processes that have shaped the soil's permeability. A complete soil profile description is also the first step toward any additional analysis of the soil, which could range from in situ hydraulic conductivity measurements to agronomic analyses. This chapter details the methods for field description of a soil profile.

Where do we begin to describe a soil? Just as the recipe for rabbit stew starts with "first find a rabbit hole," to develop a soil description, we must first locate a hole, or soil, to describe. This is not as simple as digging anywhere. The soil excavation site should be carefully chosen to represent the entire site fully (see "Principles of Site Evaluation," Lindbo et al., 2008, this publication). Often, more than one profile description will be needed. The exact number depends on such things as site and soil variability, land use intensity, and topography. The right answer to the question of how many descriptions to make is "as many as necessary." Often experience is the best guide to the number of descriptions needed. The best recommendation is first to auger/probe multiple observation points in reconnaissance, and then choose the location or locations most representative of the soil. In general, a soil pit is the most desirable method for a soil profile investigation, but a pit requires sufficient space, access, and power to dig the pit. If digging a pit is not practical, soil profile evaluations can be made using a soil probe or soil auger, with some reduction in detail.

Once soil excavation sites are determined, what to describe and the level of detail come next. The objective of the client and the proposed land use will determine the level of detail, but a soil description should usually include most if not all of the following: horizon, depth, and the soil properties of structure, color, redoximorphic features, texture, consistence, roots, and reaction (pH).

In addition, the observation method (i.e., whether the soil is exposed in a pit face or sampled with a soil probe or auger) dictates the level of detail to some extent. Each component of the description will help in the overall interpretation; however, land use makes some components more important than others. At this stage, it is also important to decide whether to be a "lumper" or a "splitter."

Lumpers tend to group similar features together, so management implications will be similar. The result of lumping is a more general description that could take less time. This type of description is useful if the overall project is also general, such as preliminary site evaluation for a large subdivision, assuming that if a detailed evaluation is needed on specific lots, this detailed analysis would be done at a later stage of the project. Splitters, on the other hand, create a more detailed description by recognizing subtle changes and recording them. The resulting description will contain more detailed information and will take longer. This type of description would be useful, for example, in an archeological investigation, where small changes and details are critical. In projects where splitting is the major mode of operation, lumping can be performed later for general management implications.

Soil Description

The soil description must be standardized to allow good communication between the soil scientist and client and to provide consistently good science and land use interpretation. Table 1 provides a suggested description form that should help standardize the procedure. Many current regulations and codes require these descriptive elements. Forms can be customized for the user and for different types of projects. Table 2 is a list of equipment generally necessary for most soil descriptions. The remainder of this chapter discusses each part of the form, terminology, and how it should be filled out.

Table 1. Soil evaluation form.

Name								
Site								
Reference Number								
Date			Time			Weather		
Vegetation								
Landscape position and description							Slope	
Aspect								
Horizon	Depth (cm)	Texture Class	Matrix Color	Redoximorphic Feature Distinctness	Redoximorphic Feature Color	Structure (grade, size, type)	Consistence (moist or dry?) (failure, rupture, stickiness, plasticity)	Other
Notes:								

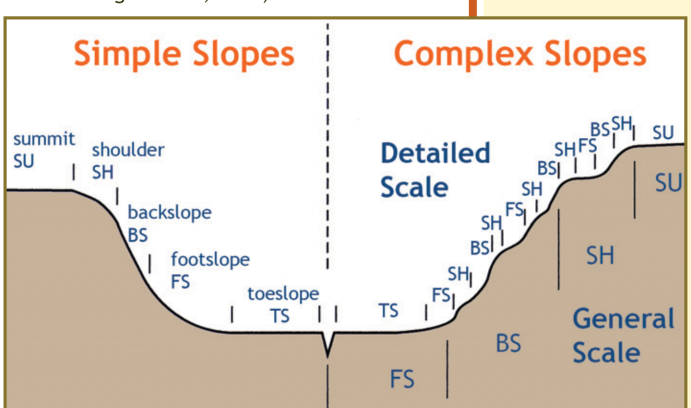
Table 2. List and description of typical soil profile evaluation equipment.

Auger or soil probe
Calculator
Camera
Clipboard
Clinometer (or Abney level or other device) for determining grade or slope
Compass (for determining the aspect)
Field book for describing soils
Field pH meter or dye kit
Flagging
Global positioning system (GPS) unit
Golf tees or nails
Knife
Munsell soil color book
Photographic scale
Plastic bags (for collecting samples for laboratory analyses)
Penetrometer (for measuring resistance)
Rock hammer
Shovel
Sieve (2 mm) for removing coarse fragments
String lines
Soil knife
Tape measure
Towel
Water bottle
Writing utensils (pencils, permanent markers)

Site Description

The chapter "Principles of Site Evaluation," Lindbo et al. (2008, this publication) reviews the process of performing an overall site evaluation, which generally prefaces more detailed soil profile descriptions. Additional information should be collected for the site immediately surrounding each soil profile that is to be described. A clinometer, Abney level, or similar device is used to determine the slope percentage or slope degree. It should be measured both above and below the pit where the soil is described. Ideally, these points should be the same, but sometimes the pit is purposely located at a slope break to describe site and soil variability. "Simple Surveying Techniques" (Simon and McIlwee, 2008, this publication) may be consulted for more information on simple site surveying practices. Like slope, landscape position and description help determine the location of the pit on the slope (Fig. 1) and then the shape

Fig. 1. Landscape position diagram for landscape cross-section (Soil Survey Staff, 1999; Schoeneberger et al., 2002).



of the slope (Fig. 2). Landscape position helps in interpreting surface water movement and lateral flow of water within the landscape.

Aspect is measured with a compass and refers to the direction the slope faces (Fig. 3; Soil Survey Staff, 1999; Schoeneberger et al., 2002). Although not critical in all regions or for all land uses, it is an easy measurement to make and record. If the site will be developed for residential or commercial use, then aspect may help an architect design a green building. These same principles may also apply to certain agronomic practices as well, particularly for such uses as orchards. Typically south and west aspects in the northern hemisphere receive the direct incidence of sunlight radiation and are drier than north- and east-facing slopes, which receive less radiant energy and are wetter. Therefore, aspect can affect the amount of biomass as well as the degree of soil wetness and, thus, soil development.

At the time the soil is described, the type and abundance of vegetation should also be recorded. This provides the client with a baseline for the site. It may help determine the level of site work needed for a given land use. For example, if the site is currently an agricultural field and the intended land use is a subdivision, then the cost to clear land will be lower than if the site were forested. Details about overall site vegetation should be included in the overall site evaluation as well. At the same time, recording the basic weather conditions is also advisable, such as whether it was sunny or overcast, clear or raining, etc., especially if any measurements pertaining to soil moisture status are collected. Good note-taking is essential. The soil profile evaluator should record as much information as possible while at the site so that he/she can "remember" the site correctly in the months and years after the soil profiles are described.

Soil Profile

The remainder of this chapter will provide the steps involved in a soil profile investigation, including siting and digging a soil pit, preparing the pit, identifying soil layers, naming soil horizons, and describing soil properties such as color, texture, structure, and horizon features.

Fig. 2. (Upper) Slope description within various landscape components (Soil Survey Staff, 1999; Schoeneberger et al., 2002). (Lower) Slope geometry descriptions for hill slope elements (Soil Survey Staff, 1999; Schoeneberger et al., 2002).

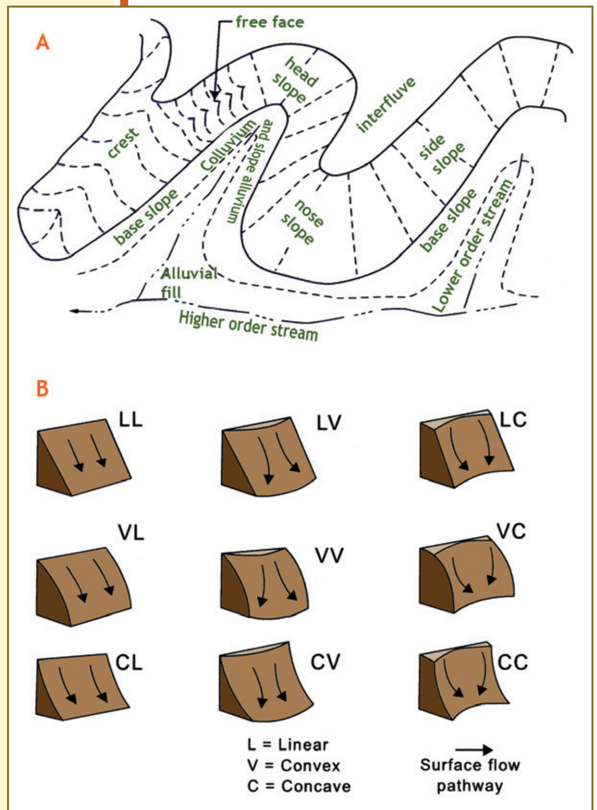


Fig. 3. Aspect.

Siting and Digging the Soil Pit

A pit (dug by hand or with a backhoe) is preferable to an auger or probe description for detailed evaluation. Describing soil structure or getting accurate horizon depths from auger samples is not always possible. On the other hand, auger or probe descriptions may be useful during a reconnaissance study because they can be done quickly and at lower cost. The tradeoff is accuracy. Sometimes it may be most practical to have soil pits dug by a professional backhoe operator, and so a preliminary auger or probe investigation of the site may help quickly determine the best placement of the pits. Additionally, auger or probe descriptions can document the range of variability once the major soil description is done.

Before digging the soil pit, determine the location of the pit face, and what time of day the profile description will occur. The pit face refers to the portion of the soil pit that will be described. The pit face should be situated so that it is in full sunlight during the description, and should be as vertical as possible. This orientation makes it much easier to determine soil color, delineate soil horizons, and photograph the soil.

Ideally, describe the profile from a pit approximately 1.2 meters (4 feet) deep. If the pit is deeper than those listed in the Occupational Safety and Health Administration (OSHA) guidelines on excavation safety (http://www.osha.gov/SLTC/trenchingexcavation/index.html), special precautions must be taken, such as shoring the walls of the soil pit or trench. Simon (2008, this publication) provides detailed information on safe soil sampling techniques.

Preparing the Pit Face and Locating Soil Layers and Horizons

Once the pit has been situated and excavated, the face needs to be cleaned of loose material and smearing so that structure and features can be more clearly observed. This is done by picking the loose material off with a knife, rock hammer, spade, or similar instrument. It is best to clean from the top down so that loose material does not fall onto areas that have already been cleaned. During the cleaning process, note changes in such things as soil texture, color, consistence, and coarse fragment content. Roots that change direction abruptly also suggest that there is a change in some soil parameter. These changes mark soil horizon breaks. During the cleaning process, it is helpful to mark horizon breaks by placing a golf tee or nail in the pit face at that point. Golf tees are inexpensive, will degrade over time if left at the site (choose wood tees), are highly visible, and float (particularly useful in soil with water in the pit).

As a general rule, the soil profile should be described systematically, either from the top down or from the bottom up. Working from the top down is especially helpful when considering processes that occur vertically, such as the movement of water through a soil profile. Describing from the bottom up is desirable for two very practical reasons. First, the material that falls during removal may mask areas you have already described, so starting at the bottom eliminates the possibility of describing contaminants (fallen soil particles) from above. Second, if the pit has a high water table and needs to be either pumped or bailed, describing the lowest horizons as soon as the pit is pumped is a good idea.

After the cleaning process is complete, stand back from the pit face a short distance and examine the appearance of the soil profile to determine if there are more horizons that need to be split out. Once the pit face is relatively smooth, it is a good time to take a photograph. Photographs, while not essential, are a good way to document the description. For photographs of the soil profile, a clear, highly contrasting measuring tape is necessary, and many are available from commercial supply catalogs.

Naming Soil Layers and Horizons

The next step in the process is to name the soil layers and horizons, although it may be necessary to revise the horizon nomenclature later after completing the rest of the profile description because new features may be discovered in the course of the investigation. Three kinds of symbols—capital letters, lower-case letters, and Arabic numerals—used in combination designate horizons and layers (see list in Table 3). Capital letters designate master horizons: O, A, E, B, C, L, M, and R horizons. Lower-case letters are used as suffixes to indicate specific characteristics of the master horizon and layer and indicate soil forming processes associated with these characteristics. Arabic numerals are used both as suffixes to indicate vertical subdivisions within a horizon and as prefixes to indicate discontinuities (Soil Survey Staff, 1993; Schoeneberger et al., 2002). Genetic horizons are not the equivalent of the diagnostic horizons of U.S. soil taxonomy (Soil Survey Staff, 1999), most recently updated in the tenth edition of *Keys to Soil Taxonomy* (Soil Survey Staff, 2006). Designations of genetic horizons express a qualitative judgment about the vector of changes and the intensity of soil genesis that may have occurred. The breaks may be adjusted as more soil property data is collected. Weathered bedrock, designated with a Cr, and hard bedrock, designated with an R, may also be described in an exposure. Weathered or hard bedrock would limit land use and is thus an important feature to record.

Occasionally, the describer may be unsure which horizon is present or may find properties of two adjacent master horizons. This can be designated in the profile description through the use of specific transitional horizons, of which there are two kinds. In one, the horizon is dominated by properties of one master horizon but with subordinate (lesser) properties of another. Two capital letter symbols are used in sequence, such as AB, EB, BE, or BC. The master horizon symbol is given first and designates the kind of master horizon whose properties dominate the transitional horizon. For example, a subsurface horizon below the A horizon may exhibit the color and texture of the A horizon above it while having structure similar to the B horizon below it. In this case, the horizon would be referred to as an AB horizon. In the other type distinct parts of the horizon have discrete recognizable properties of the two master horizons indicated by the capital letters. The two capital letters are then separated by a slash (/), as E/B, B/E, or B/C. The first symbol is for the horizon that makes up the greater volume. Further changes to horizon names can be made after all the field properties are described, so the designation accurately describes the horizon.

Table 3. Horizon nomenclature (Soil Survey Staff, 2006).

Master Horizons and Layers	
O horizons	Layers dominated by organic material.
L horizons	Layers that were either deposited in water by precipitation or through the actions of aquatic organisms, such as algae and diatoms, or derived from underwater and floating aquatic plants and subsequently modified by aquatic animals.
A horizons	Mineral horizons that formed at the surface or below an O horizon that exhibit obliteration of all or much of the original rock structure and (i) are characterized by an accumulation of humified organic matter intimately mixed with the mineral fraction and not dominated by properties characteristic of E or B horizons; or (ii) have properties resulting from cultivation, pasturing, or similar kinds of disturbance.
E horizons	Mineral horizons in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these, leaving a concentration of sand and silt particles of quartz or other resistant materials.
B horizons	Horizons that formed below an A, E, or O horizon and are dominated by obliteration of all or much of the original rock structure and show one or more of the following: 1. illuvial concentration of silicate clay, iron, aluminum, humus, carbonates, gypsum, or silica, alone or in combination 2. evidence of removal of carbonates 3. residual concentration of sesquioxides 4. coatings of sesquioxides that make the horizon conspicuously lower in value, higher in chroma, or redder in hue than overlying and underlying horizons without apparent illuviation of iron 5. alteration that forms silicate clay or liberates oxides or both and that forms granular, blocky, or prismatic structure if volume changes accompany changes in moisture content 6. brittleness 7. Formation of pedogenic structure
C horizons or layers	Horizons or layers, excluding hard bedrock, that are little affected by pedogenic processes and lack properties of O, A, E, or B horizons. The material of C horizons may be either like or unlike that from which the solum presumably formed. The C horizon may have been modified even if there is no evidence of pedogenesis. A Cr horizon is weathered, soft bedrock that can be dug by hand. A Cr horizon must not slake in water. If it slakes in water it should be considered a C horizon.
R layers	Hard bedrock including granite, basalt, quartzite and indurated limestone or sandstone that is sufficiently coherent to make hand digging impractical.
M layers	Root-limiting subsoil layers consisting of nearly continuous, horizontally oriented, human-manufactured materials Examples of materials designated by the letter M are geotextile liners, asphalt, concrete, rubber, and plastic.
W layers	Water layers within or beneath the soil. The water layer is designated as Wf if it is permanently frozen and as W if it is not permanently frozen. The W (or Wf) designation is not used for shallow water, ice, or snow above the soil surface.
	^ Adding this symbol to any master horizon denotes the material has been disturbed as in fill.
Transitional Horizons	
AB	A horizon with characteristics of both an overlying A horizon and an underlying B horizon, but which is more like the A than the B.
EB	A horizon with characteristics of both an overlying E horizon and an underlying B horizon, but which is more like the E than the B.
BE	A horizon with characteristics of both an overlying E horizon and an underlying B horizon, but which is more like the B than the E.
BC	A horizon with characteristics of both an overlying B horizon and an underlying C horizon, but which is more like the B than the C.
CB	A horizon with characteristics of both an overlying B horizon and an underlying C horizon, but which is more like the C than the B.
E/B	A horizon comprised of individual parts of E and B horizon components in which the E component is dominant and surrounds the B materials.
B/E	A horizon comprised of individual parts of E and B horizon in which the E component surrounds the B component but the latter is dominant.

Table continued.

B/C	A horizon comprised of individual parts of B and C horizon in which the B horizon component is dominant and surrounds the C component.
Subordinate Distinctions within Master Horizons and Layers	
a	Highly decomposed organic material where rubbed fiber content averages <1/6 of the volume.
b	Identifiable buried genetic horizons in a mineral soil.
c	Concretions or nodules with iron, aluminum, manganese or titanium cement.
co	Coprogenous earth, used only with an L horizon, to indicate a limnic layer of coprogenous earth, or sedimentary peat.
d	Physical root restriction, either natural or manmade such as dense basal till, plow pans, and mechanically compacted zones.
di	Diatomaceous earth, used only with an L, indicates a limnic layer of diatomaceous earth.
e	Organic material of intermediate decomposition in which rubbed fiber content is 1/6 to 2/5 (17—40%) of the volume.
f	Frozen soil in which the horizon or layer contains permanent ice.
ff	Dry permafrost for a horizon or layer that is continually colder than 0°C and does not contain enough ice to be cemented by ice. Not used for horizons or layers that have a temperature warmer than 0°C at some time of the year.
g	Strong gleying in which iron has been reduced and removed during soil formation or in which iron has been preserved in a reduced state because of saturation with stagnant water.
h	Illuvial accumulation of organic matter in the form of amorphous, dispersible organic matter-sesquioxide complexes.
i	Slightly decomposed organic material in which rubbed fiber content is more than about 2/5 (40%) of the volume.
j	Accumulation of jarosite, a potassium or iron sulfate mineral, usually an alteration product of pyrite that has been exposed to an oxidizing environment. Jarosite has a hue of hue of 2.5Y or yellower and normally has chroma of 6 or more, although chromas as low as 3 or 4 have been reported.
jj	Evidence of cryoturbation, including irregular and broken horizon boundaries, sorted rock fragments, and organic soil materials occurring as bodies and broken layers within and/or between mineral soil layers. The organic bodies and layers are most commonly at the contact between the active layer and the permafrost.
k	Accumulation of pedogenic carbonates, commonly calcium carbonate.
kk	Engulfment of horizon by secondary carbonates, used when the soil fabric is plugged with fine grained pedogenic carbonate (50% or more, by volume) that occurs as an essentially continuous medium.
m	Continuous or nearly continuous cementation or induration of the soil matrix by carbonates (km), silica (qm), iron (sm), gypsum (ym), carbonates and silica (kqm), or salts more soluble than gypsum (zm).
ma	Marl, used only with an L horizon, indicates an limnic layer of marl.
n	Accumulation of sodium on the exchange complex sufficient to yield a morphological appearance of a natric horizon.
o	Residual accumulation of sesquioxides.
p	Plowing or other disturbance of the surface layer by cultivation, pasturing or similar uses.
q	Accumulation of secondary silica.
r	Weathered or soft bedrock including saprolite; partly consolidated soft sandstone, siltstone or shale; or dense till that roots penetrate only along joint planes and are sufficiently incoherent to permit hand digging with a spade.
s	Illuvial accumulation of sesquioxides and organic matter in the form of illuvial, amorphous, dispersible organic matter—sesquioxide complexes if both organic matter and sesquioxide components are significant and the value and chroma of the horizon are >3.
ss	Presence of slickensides.
t	Accumulation of silicate clay that either has formed in the horizon and is subsequently translocated or has been moved into it by illuviation.
u	Presence of human manufactured materials or artifacts, This symbol indicates the presence of manufactured artifacts that have been created or modified by humans, usually for a practical purpose in habitation, manufacturing, excavation, or construction activities. Examples of artifacts are processed wood products, liquid petroleum products, coal, combustion by-products, asphalt, fibers and fabrics, bricks, cinder blocks, concrete, plastic, glass, rubber, paper, cardboard, iron and steel, altered metals and minerals, sanitary and medical waste, garbage, and landfill waste.
v	Plinthite which is composed of iron-rich, humus-poor, reddish material that is firm or very firm when moist and that hardens irreversibly when exposed to the atmosphere under repeated wetting and drying.

Table continued.

Table 3. Continued.

w	Development of color or structure in a horizon but with little or no apparent illuvial accumulation of materials.
x	Fragic or fragipan characteristics that result in genetically developed firmness, brittleness, or high bulk density.
y	Accumulation of gypsum.
z	Accumulation of salts more soluble than gypsum.

Sometimes, describing disturbed or non-soil layers may be appropriate, especially if they occur in appreciable amounts at the site to be described. For example, layers of sediment, gravel, or other materials may have been deposited on the site over time, which would affect the movement of water through the soil profile. In some cases, this material might need to be removed before the site can be used for a new purpose (such as a lawn or landscaping), which could result in significant costs and which the contractor might want to know ahead of time. Addition of the ^ symbol to any master denotes a disturbed horizons. The master horizon "M" and "u" suffix symbols were recently added to *Soil Taxonomy* (Soil Survey Staff, 2006) to denote layers that result from human activities. Examples may include geotextile liners, asphalt, concrete, rubber, and plastic. Another example might be the compacted layers of manure and sediment deposited in a cattle feedyard. The presence and features of any disturbed or non-soil layers present at the site may be important, and recent additions to *Soil Taxonomy* (Soil Survey Staff, 2006) give these horizons standard nomenclature.

Horizon Depth and Topography

At this point, the describer should record the horizon depths (0–10 cm, 10–24 cm, etc.) and the topography and distinctness of the horizon boundaries (Fig. 4, Table 4). The units used for determining horizon depth (inches, centimeters, meters, etc.) should be indicated on the description form. The topography refers to the shape of the soil boundary. Possible choices include smooth, wavy, irregular, and broken. Describing the boundary topography for profiles sampled with an auger or soil probe is not possible. The boundary distinctness describes the distance over which the change in the properties of the soil horizon occurs. Once you are satisfied with the horizons, depths, and boundaries, then the pit should be photographed. If for some reason horizon designations change, then more photographs may be needed.

Fig. 4. Boundary topography (Soil Survey Staff, 1999; Schoeneberger et al., 2002).

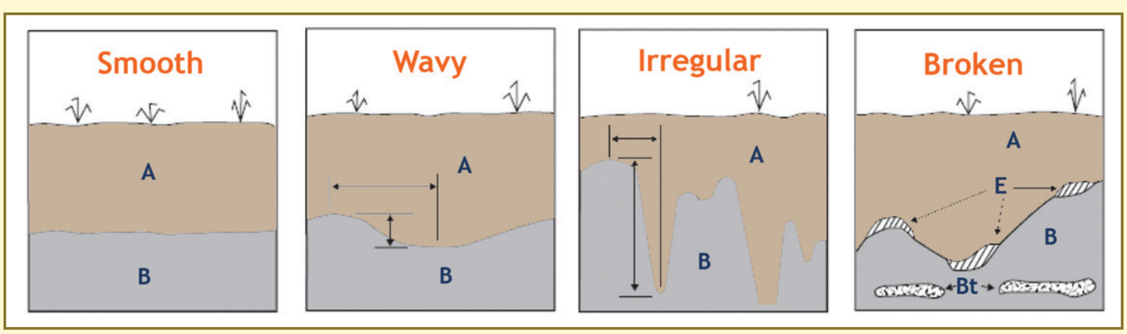


Table 4. Horizon boundary distinctness, modified from Schoeneberger et al. (2002). The thickness describes the distance over which the change in soil properties occurs.

Distinctness	Thickness
Very abrupt	<0.5 cm
Abrupt	0.5 to <2 cm
Clear	2 to <5 cm
Gradual	5 to <15 cm
Diffuse	≥15 cm

Systematic Methods for Describing Properties

Soil morphology deals with the form and organization of a soil profile. The remainder of this chapter is dedicated to a discussion of selected soil properties, and the field techniques used to determine them. For information on additional soil properties, the reader is encouraged to visit http://soils.usda.gov/scientists.html or refer to Schoeneberger et al. (2002).

The sequence in which parameters are described is a matter of personal preference. A logical sequence is presented here that starts with dry, clean hands and then moves on to properties that get the hands progressively wetter and messier. From experience, the best order in which to describe soil properties is the following:

- soil structure
- color of both the matrix and redoximorphic features
- other soil properties, including texture, consistence, roots, and reaction (pH)

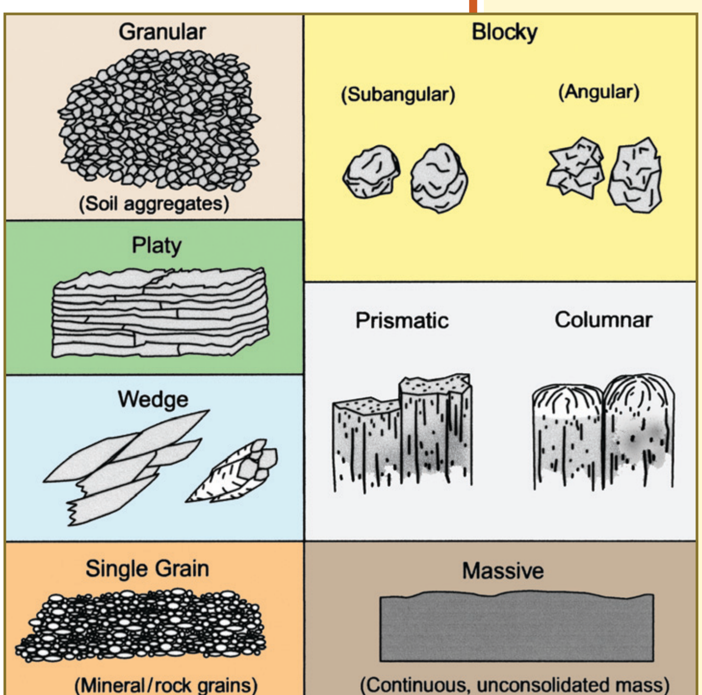
These are the most important properties, and they should be described for all soil profiles. If the soil profile contains a very large amount of organic material (more than 50% of the upper 40 cm), describe the type and abundance of organic fibers, not the texture. After texture, describe the consistence, any roots present, and the pH using either a field pH meter or commercially available dye kit. In each of the following sections, the soil property will be explained, followed by a description of how to measure or assess the property.

Soil Structure

Soil structure conveys a great deal of information about how liquids and gases will move in a soil profile. One definition of soil structure is the arrangement of individual soil particles into a larger grouping, sometimes called a **ped**. One can also think of structure as a brick house—the brick, mortar, and cement are the particles (i.e., texture), and the completed geometry of the house is the structure. Structure relates to water, air, and root movement. Consider a soil with a structure that does not allow roots to penetrate deeply into the soil. Agricultural crops will suffer water stress because the plants will be unable to use water with depth in the soil profile; their roots cannot penetrate that far. One effect of shallow rooting is the occurrence of a tree throw during wind gusts because a tree with roots that do not penetrate the soil may not be well anchored and can tip over, exposing the root system. Three components describe soil structure: type, grade, and size.

Types of Soil Structure. There are seven classes or types: granular, angular blocky, subangular blocky, platy, wedge, prismatic, and columnar (Fig. 5). Typically, **granular** structure looks like granola and is most often found in the surface layers with appreciable organic matter levels. **Angular blocky** structure is equidimensional with the faces at sharp angles and the peds fitting together well. **Subangular blocky** structure has more rounded than angular corners and edges. **Platy** structure is characterized by horizontal planes. **Wedge** structure has elliptical interlocking peds and often show slickensides (i.e., stress surfaces that are polished and striated produced by one mass sliding past another). **Prismatic** structure is vertically elongated. **Columnar** structure is similar to prismatic, but the unit tops are frequently rounded and bleached. Columnar structure is associated with horizons that are high in salts, and the salts likely cause this type of structure to form.

Fig. 5. Structure types or classes (Soil Survey Staff, 1999; Schoeneberger et al., 2002).



Structureless soils can be described as either single grained or massive. **Single grained** means that there is no cohesion between soil particles, and thus, no soil structure. Single grain refers to non-cohesive sands, whereas massive refers to any soil that does not break into any predictable and/or repeatable type or shape. **Massive** means that there is no arrangement of soil particles into "real" structural units. Another type of massive structure, proposed here by the chapter authors, is called massive-rock controlled fabric. **Massive-rock controlled** structure describes soil developed from saprolite, which is weathered bedrock. Unlike simple massive structure, massive-rock controlled fabric may have a preferred orientation due to the minerals present in the parent rock. The material may easily break into the individual mineral grains.

Sizes of Soil Structure. Size falls into five categories. The actual size ranges vary depending on the type (class) of structure and are given in Table 5. Note that the size ranges for platy refers to the thickness of the plates, and columnar and prismatic refer to the diameter of the columns or prisms.

Table 5. Size chart for structure units, modified from Schoeneberger et al. (2002).

Class†	Size‡		
	Granule or plate thickness	Column, prism, or wedge diameter	Angular or subangular blocky
	mm		
Very fine or very thin	<1	<10	<5
Fine or thin	1 to <2	10 to <20	5 to <10
Medium	2 to <5	20 to <50	10 to <20
Coarse or thick	5 to <10	50 to <100	20 to <50
Very coarse or very thick	≥10	100 <500	≥50
Extremely coarse	-	≥500	-

† Thin is only used for plates.

‡ Size is for the smallest dimension in millimeters.

Grades of Soil Structure. Grade refers to how well expressed or how stable the soil structure is. There are four groups of structure grade (0–3). All structureless soil materials have a grade of 0. The others grades range from 1 for weak, 2 for moderate, and 3 for strong structure. **Structureless** means the soil has no discrete units observable in place or in a hand sample. **Weakly structured** soils have units that are barely observable in place or in a hand sample. **Moderate** structures have well-formed units that are evident in place or in a hand sample. **Strong** structures are units that are distinct in place (undisturbed soil) and separate cleanly when disturbed. Compound structure is described when smaller structural units are held together to form larger units. For example a soil may be described as having “Moderate coarse prismatic structure parting to strong medium subangular blocky structure.” In that example, the prismatic structural units were large and broke into smaller subangular blocky units.

How do I assess soil structure in the field? To describe soil structure, begin by looking at the pit face for the shape of the peds. If obvious shapes are not apparent, the soil will have a weak structure or may be structureless. If peds are somewhat obvious, the structure is moderate, and if obvious and easily removed in a hand sample with retention of that shape, then the structure is strong. To differentiate between weak and structureless, remove a section of the soil and see how it breaks apart naturally. If the soil breaks apart in a regular and predictable fashion, but no structure could be seen in the pit face, then the structure is weak. If breaks are random, then the soil is structureless. A structureless soil composed of unconsolidated particles (sand) is single grained. If it is coherent and lacks what appears to be rock fabric, then the structure is massive. If a definite rock fabric is visible, then the structure is massive-rock controlled fabric. Use Fig. 5 to determine shape, and Table 5 to determine size.

Soil Color

Soil color is described next. Color is perhaps the most obvious and easily determined soil property. Extremely important site characteristics, such as drainage, mineral weathering, and water content, can be inferred from soil color. Organic matter darkens the soil and is typically associated with surface layers, usually masking all other coloring agents. Well-drained soils often have uniform and bright colors. Iron is the primary coloring agent in the subsoil. The orange-brown colors associated with well-drained soils are the result of iron oxide stains that coat individual particles. Soils with a fluctuating water table usually have a mottled, or spotted, pattern of gray, yellow, and/or orange colors. Very poorly drained soils have a high water table for a significant portion of the year and will have very gray background or matrix colors. The word **gley** is used for gray, poorly drained soils. Poorly drained soils will pose significant land use challenges unless they are artificially drained. Manganese is common in some soils and results in very dark black or purplish black spots or stains. Several other soil minerals have distinct colors, thus making their identification straightforward. For example, glauconite is green, quartz has various colors but is often white or gray, feldspars range from pale buff to white, kaolinite appears gray to white, and micas may be white, brownish black, or golden.

Color determination can be quite subjective if only a verbal description is used. In general, people perceive colors differently, so a standard reference is a needed. The Munsell Color system is the standard used in soil science, as well as many industries, and Munsell soil color books can be purchased from many research and industry supply catalogs. The system describes three components of color: hue, value, and chroma.

Soil Color Hue, Value, and Chroma. **Hue** refers to the dominant wavelength of reflected light (e.g., red, yellow, green). **Value** refers to the lightness or darkness of a color in relation to a neutral gray scale. Value extends from pure black (0/) to pure white (10/) and is a measure of the amount of light that reaches the eye. Gray is perceived as about halfway between black and white and has a value notation of 5/. Lighter colors have values between 5/and 10/; darker colors lie between 5/ and 0/. **Chroma** is the relative purity or strength of the hue. Chroma indicates the degree of saturation of neutral gray by the spectral color. Chromas extend from /0 for neutral colors to /8 as the strongest expression of the color. The typical notation of color is an alphanumeric term of hue value/chroma such as 10YR 5/6. Some colors have symbols such as N 6/, a totally achromatic (neutral color) designation with no hue or chroma, only a value.

Gley Soil Colors. Gley colors are a specific group of colors that generally refer to soil that formed under saturated conditions. The gley page is set up differently from the other pages. Hue is along the bottom with value increasing along the Y axis, and for colors with a chroma of 0, hue is N, with 1 or 2 for other hues. Checking the page that faces the gley page in the Munsell color book will indicate the chroma being used.

How do I assess soil color in the field? Colors should be recorded under consistent light conditions. Soil should be moist to determine soil color because moist soil is darker than dry soil. Thus, determining color may require adding some water to the sample. Although using moist samples is the most common way to determine soil colors, they can also be recorded in the dry state. However, at all times, the moisture status of the sample should be noted. Always use a freshly exposed face or ped and record what is being assessed. Soil colors should be determined on an intact soil ped so that colors of various soil fabric features can be identified. Colors must always be determined in natural light (direct sunlight) with the sun behind the person describing the soil. Furthermore, colors should not be determined late or early in the day because the sun angle can alter the observed color. Colors should not be determined under artificial light. Finally, the describer should not determine color while wearing sunglasses or tinted glasses.

Matrix and Redoximorphic Feature Colors. In describing colors, determining the variation in color throughout the soil is important. Matrix color is the dominant color of the horizon. Some horizons have several colors. The dominant color is recorded first, followed in sequence by those of lesser content. Redoximorphic features result from the reduction, oxidation, and translocation of iron and/or manganese. Mottles are color patterns not necessarily related to soil wetness, but often related to parent material, mineralogy, or weathering patterns. Other color patterns may be described separately for any feature such as peds, concretions, nodules, cemented bodies, filled animal burrows, etc. Gley colors are low chroma matrix colors with or without mottles. If the soil has a gley color, then it is likely to be reduced and wet for some portion of the year. Likewise the percentage of the given feature should be recorded. Indicate the abundance of mottles and redoximorphic features by recording the actual percentage using the charts available in the front portion of the Munsell soil color book to determine the percentage estimate.

Contrast in Redoximorphic Features. The level of contrast is assessed after the matrix color and the redoximorphic color is determined. The level of contrast can be assigned by comparing the color of the redoximorphic feature with the color of the matrix, using Table 6. There are three classes of contrast: faint, distinct, and prominent. Faint contrast is evident only on close examination. Distinct contrast is readily seen, but is only moderately different from the matrix color. Prominent contrast indicates strongly contrasting colors.

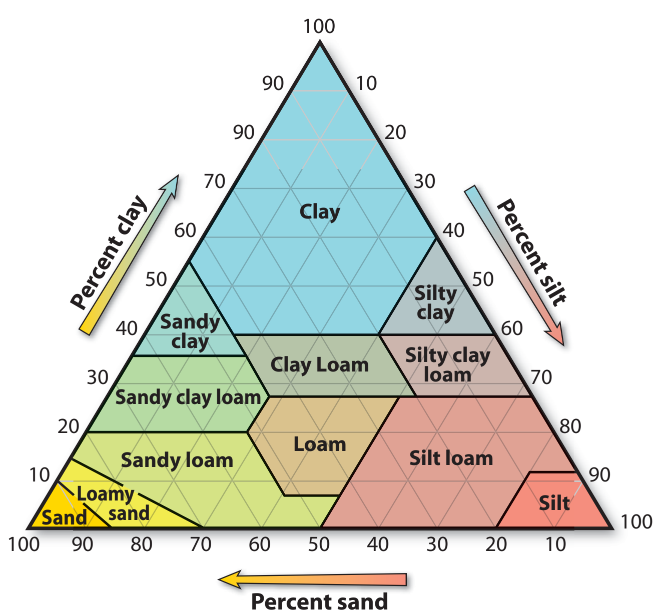
Table 6. Contrast chart for soil mottling and redoximorphic features, modified from Schoeneberger et al. (2002).

Contrast	Difference in color between matrix and mottle			
Hue	Value	Chroma		
Faint	same	0 to <2	and	<1
Distinct	same	>2 to <4	and	<4
			or	
	same	<4	and	>1 to <4
	1 page	<2	and	<1
Prominent	same	>4	or	>4
	1 page	>2	or	>1
	2+ page	>0	or	>0

Texture by Feel

Soil texture by feel should come next in the description. Determining texture requires a moister sample than color analysis. **Texture** itself refers only to the amount of sand, silt, and clay in the soil (Fig. 6). Soil texture allows inferences about pore size, water movement, and water-holding capacity. **Particle size distribution** describes the abundance of the various particle sizes that constitute the mineral portion of soil materials and is a laboratory procedure. Therefore, texture and particle size distribution are not quite synonymous, although both are used to quantify and describe the amount of sand, silt, and clay particles in a given soil sample. The finer fractions are called the fine earth fraction (smaller than 2-mm diameter). In the U.S. system, sand is defined as 2 to 0.05 mm in diameter, silt is 0.05 to 0.002 mm, and clay particles are less than 0.002 mm in diameter. A flow chart (Fig. 7) provides the basis for texture determination by feel (Thien, 1979).

Fig. 6. Soil textural triangle.



How do I measure soil texture in the field? An excellent way to learn how to determine texture is to use known samples as reference points. Known samples can often be obtained from other geoscientists. A collection of reference samples can also be collected by submitting selected soil samples to an analytical laboratory for particle size determination, while retaining a portion of the soil sample. After obtaining the laboratory results, estimates can be compared with laboratory results. Over time, practice gives greater proficiency with feeling the soil texture.

The larger particles (pebbles, cobbles, stones, and boulders) are called rock fragments. The term **coarse fragments** excludes the stone and boulder classes in the rock fragments. Particle-size distribution of fine earth fraction is determined in the field mainly by feel (Fig. 7). The rock fragment content is determined by estimating their proportion in the soil volume. To determine soil texture by feel, it may be necessary to remove rock fragments from the soil sample using a 2-mm sieve.

Fig. 7. Determination of soil texture flow chart, modified from Thien (1979).

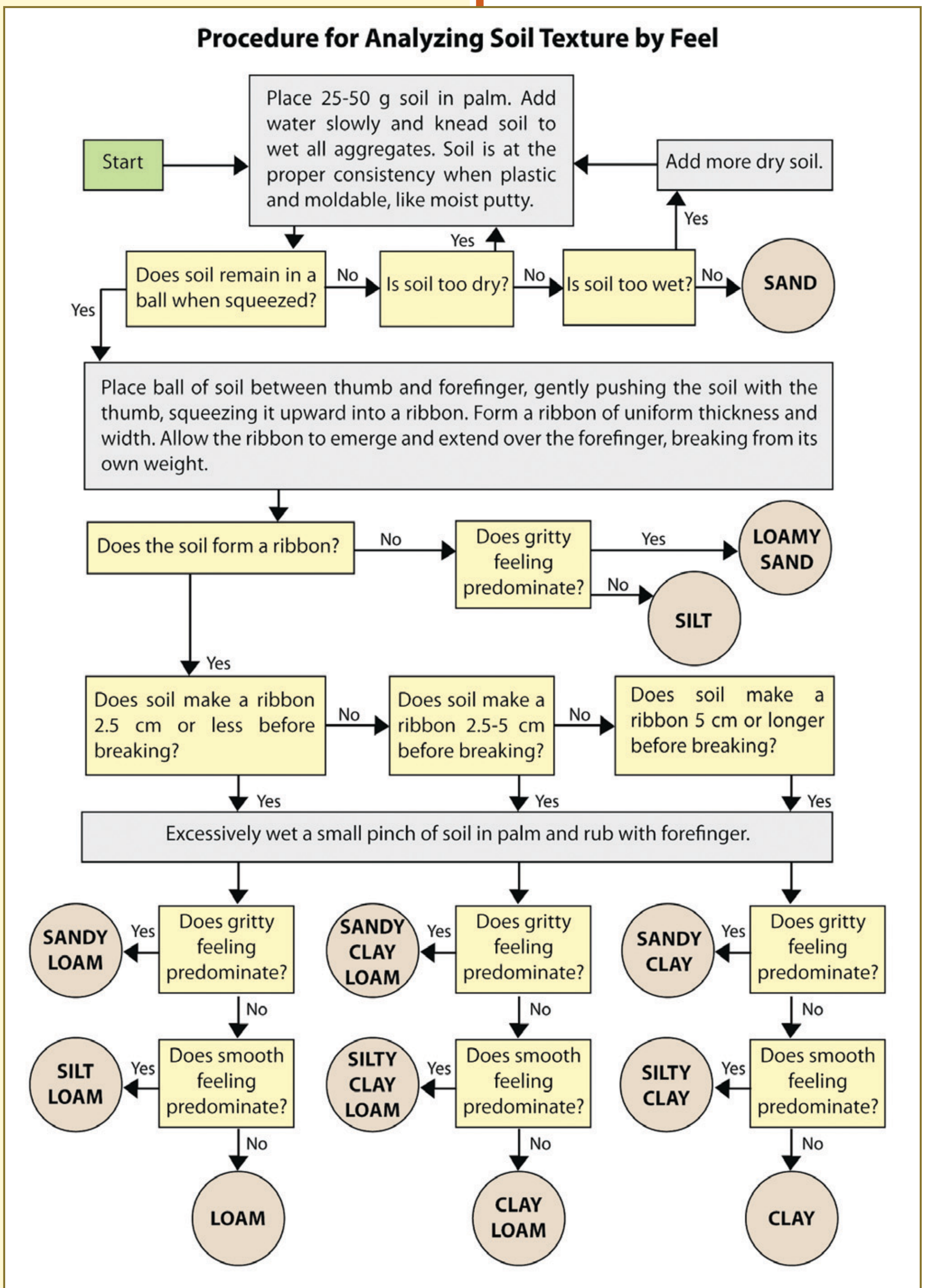
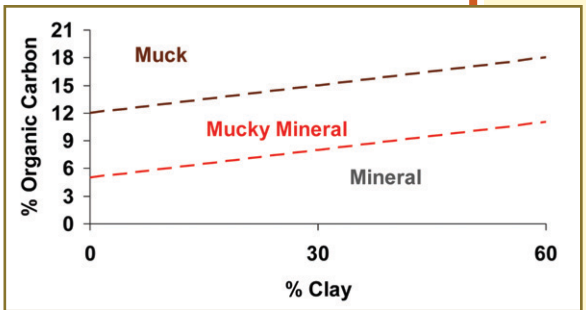


Fig. 8. Organic soil-clay relation.



How do I measure soil organic material by feel in the field? Soil organic matter influences soil by acting as a coloring agent, improving the water holding capacity, increasing fertility, and improving aggregation. The type and abundance of organic material in the soil affects the way the texture feels. Organic matter may feel smooth (like silt) and sticky (like clay) and thus interferes with the feel of the soil texture. Organic matter is approximately 1.7 times the organic carbon content. A soil is divided into three classes based on the organic carbon content relative to clay: **muck**, **mucky mineral**, and **mineral** (Fig. 8).

Organic matter content can be determined in the laboratory or in the field. For field determination, having known standards for calibration is best. Not only is amount of organic matter important, but also knowing how decomposed the materials are within the soil horizon. There are three types of soil organic materials: **sapric** (Oa)—very decomposed, <17% rubbed fibers; **hemic** (Oe)—decomposed, 17 to 40% rubbed fibers; **fibric** (Oi)—least decomposed, >40% rubbed fibers.

To identify organic soils, rub a moist sample between fingers 10 times. Examine material with a hand lens and look for fibers (not live roots) and estimate percentage fibers remaining. Fibers are smaller than 2 cm (approx. 1 inch) and exhibit cellular structure. Muck is highly decomposed, <1/6 fibers remaining after rubbing (sapric material). Mucky peat is moderately decomposed, between 1/6 and 3/4 remaining after rubbing (hemic material). Peat is slightly decomposed, >3/4 fibers remaining after rubbing (fibric material).

Consistence

Consistence is the degree and kind of cohesion and adherence that soil exhibits and/or the resistance of soil to deformation or rupture under applied stress. Consistence relates to other soil properties. Perhaps the most critical are water movement and overall management considerations. Aspects of consistence determine whether the horizon or soil will have low permeability. Essentially, as consistence increases, the rate of water movement decreases. Soil consistence can also relate to the presence of other materials, such as volcanic ash or organic matter. Soils with the greatest consistencies are often high in clay content.

There are five ways to record consistence in the field: rupture resistance, manner of failure, stickiness, plasticity, and penetration resistance. Each type is recorded at specific moisture contents, or within given moisture content ranges, resulting in a measure of the strength of the soil to withstand an applied stress. Moisture content for consistence tests should be indicated on the description sheet. If they are available, dry peds can be used in determining dry consistence. If all of the peds are dry, a moist sample can be prepared by placing the peds on a sponge or wet towel until moistened. Often, even in freshly excavated pits, the peds will need some water added to determine moist consistence. Determining consistence requires adding more water to the sample and can be quite messy. This is why it is a good idea to describe consistence toward the end of the soil profile description.

Measuring Rupture Resistance Consistence in the Field. Rupture resistance is a measure of the strength of soil material to withstand an applied stress and can be determined under either dry or moist conditions (Table 7). Obtain a block-like specimen that is about 2.5 to 3 cm on edge. (If the soil structure shape is platy, use a plate that is about 1.0 to 1.5 cm long and 0.5 cm thick). Failure occurs when deformation or rupture is first detected. Stress should be applied over 1 second. Compress the specimen between the thumb and forefinger. If it does not rupture, squeeze the block between both hands. If it still doesn't rupture, place it under your foot and press it against a nonresilient, flat surface. If a specimen resists rupture by compression, a weight may be dropped onto it from increasingly greater heights until it ruptures.

Table 7. Rupture resistance classes for block-like specimens (Soil Survey Staff, 1999; Schoeneberger et al., 2002).

Dry class	Moist class	Operation	Stress applied†
Loose	Loose	Specimen not obtainable	-
Soft	Very friable	Very slight force between fingers	<8 N
Slightly hard	Friable	Slight force between fingers	8-20 N
Moderately hard	Firm	Moderate force between fingers	20-40 N
Hard	Very firm	Strong force between fingers	40-80 N
Very hard	Extremely firm	Moderate force between fingers	80-160 N
Extremely hard	Slightly rigid	Foot pressure full body weight	160-800 N
Rigid	Rigid	Blow of <3J but not body weight	800 N < 3 J
Very rigid	Very rigid	Blow of ≥ 3J	≥3 J

† Both force (newtons, N) and energy (joules, J) are used. The number of newtons is 10 times the kilograms of force. Three joules is the energy delivered by dropping 2 kg weight 15 cm. Firm is considered limiting for onsite wastewater treatment.

Measuring Manner of Failure Consistence in the Field. The manner of failure relates to the rate of change and the physical condition soil material attains when subjected to compression. The manner of failure depends on water state when the sample is either moist or wet (Table 8). To evaluate the manner of failure, a block-like specimen 2.5 to 3 cm on edge is pressed between thumb and forefinger and/or a handful of soil material is squeezed by hand. The three failure classes are **brittleness**, **fluidity**, and **smeariness**. Each class uses a different size sample. The smeariness failure class indicates andic or spodic materials and relates to their unique mineralogy (andic) and form of organic matter (spodic). Andic materials are volcanic ash, and spodic materials are organic matter that has moved vertically in a soil profile. The brittleness test can be used to describe fragipans.

Table 8. Manner of failure classes modified from Schoeneberger et al. (2002).

Brittleness	Use a 3 cm block, press between thumb and forefinger.
Brittle	Block ruptures abruptly (pops or shatters)
Semi-deformable	Block ruptures before compression to less than one-half original thickness
Deformable	Block ruptures after compression to greater than or equal to one-half original thickness
Fluidity	Use a palmful of soil, squeeze in hand.
Non-fluid	No soil flows through fingers with full compression
Slightly fluid	Some soil flows through fingers, most remains in palm, after full pressure
Moderately fluid	Most soil flows through fingers, some remains in palm, after full pressure
Very fluid	Most soil flows through fingers, very little remains in palm, after gentle pressure
Smeariness	Use a 3-cm block, press between thumb and forefinger.
Non-smeary	At failure, block does not change abruptly to fluid, fingers do not skid, no smearing occurs
Weakly smeary	At failure, block changes abruptly to fluid, fingers skid, soil smears, little or no water remains on fingers
Moderately	At failure, block changes abruptly to fluid, fingers skid, soil smears, some water remains on fingers
Strongly smeary	At failure, block changes abruptly to fluid, fingers skid, soil smears and is slippery, water easily seen on fingers

Measuring Stickiness and Plasticity Consistence in the Field. The soil stickiness is the capacity of soil material to adhere to other objects. To measure this, a sample of soil is crushed in the hand, and water is applied while manipulating with thumb and forefinger. Stickiness is estimated at the moisture content that displays maximum adherence between thumb and forefinger (Table 9). Soil plasticity is the degree to which puddled or reworked soil material can be permanently deformed without rupturing. The evaluation is made by forming a roll of soil at the water content where the maximum plasticity is expressed (Table 10). This can be done by taking the wet sample used to measure stickiness and rolling it back and forth between the palms of your hands. The goal is to try and form the longest, thinnest roll possible. Compare the roll with the parameters given in Table 10.

Table 9. Stickiness classes for soil consistence (Soil Survey Staff, 1999; Schoeneberger et al., 2002).

Class	Criteria
Non-sticky	Little or no soil adheres to fingers after release of pressure.
Slightly sticky	Soil adheres to both fingers after release of pressure with little stretching on separation of fingers.
Moderately sticky	Soil adheres to both fingers after release of pressure with some stretching on separation of fingers.
Very sticky	Soil adheres firmly to both fingers after release of pressure with much stretching on separation of fingers.

Table 10. Plasticity classes for soil consistence.

Class	Criteria
Non-plastic	Will not form a 6-mm-diameter roll, or if formed, cannot support itself if held on end.
Slightly plastic	6-mm-diameter roll supports itself; 4-mm-diameter roll does not.
Moderately plastic	4-mm-diameter roll supports itself; 2-mm-diameter roll does not.
Very plastic	2-mm-diameter supports itself.

Measuring Penetration Resistance Consistence in the Field. Penetration resistance is the ability of soil in a confined (field) state to resist penetration by a rigid object of specific size. Classes (Table 11) are based on the pressure required to push the flat end of a cylindrical rod with a diameter of 6.4 mm a distance of 6.4 mm into the soil in about 1 second. A cone penetrometer is one tool that can be used to measure the penetration resistance.

Table 11. Penetration resistance classes (Soil Survey Staff, 1999; Schoeneberger et al., 2002).

Class	Criteria
	MPa
Extremely low	<0.01
Very low	0.01 to <0.1
Low	0.1-1
Moderate	1-2
High	2-4
Very high	4-8
Extremely high	≥8

Roots

Quantifying Root Size and Abundance in the Field. Another parameter of interest is the presence of roots. The presence of many plant roots is a very obvious sign that the soil has supported vegetation in the past and likely has a consistency that will favor plant growth in the future. Roots are described in terms of size (diameter) and abundance. Measure the diameter of the roots to determine size and compare to the sizes described in Table 12. To assess abundance, the number of roots in a given area should be counted. For very fine and fine roots, count the number of roots in a square centimeter–sized area. For medium and coarse-sized roots, count the number of roots in a 10 square centimeter–sized area. For very coarse roots, count the number present in an area that is 100 cm by 100 cm in size.

Table 12. Root size classes (Soil Survey Staff, 1999; Schoeneberger et al., 2002).

Size	Diameter
	mm
Very fine	<1
Fine	1 to <2
Medium	2 to <5
Coarse	5 to <10
Very coarse	≥10

In addition to size and abundance, direction should also be noted. Roots that change direction abruptly suggest some change in one or more soil parameters. Noting root growth direction may help in interpreting the soil description. Roots that appear flattened may suggest the soil shrinks and swells or moves, thus causing stress that results in reshaping the roots.

Soil Reaction (pH)

Soil reaction is synonymous with soil pH. Soils with neutral pH (approximately pH 5.5 to 7.5) can generally support most types of vegetation. If the site is to be used for growing a crop, a lawn, or landscaping, it may be important to collect this data. A step-by-step guide for measuring soil pH and lime is available in another chapter (Lund, 2008).

Determining Soil pH in the Field

Collecting soil samples and submitting them to a commercial laboratory for pH and other laboratory measurements is one possibility. However, soil reaction or pH can be determined in the field with a pH meter and pH probe or with dyes. Many commercial catalogs offer tools and products for measuring pH in the field. The procedure for measuring pH is described elsewhere in this book (Lund, 2008).

Conclusions

Soil profile descriptions form the foundation for a variety of land use interpretations. All other tests performed on the soil need to relate back to the soil profile. The process of describing the soil begins with an understanding and description of the site. Selecting the location for the profile description itself requires considering both topography and potential variability. Once a pit has been excavated, the soil profile description can be done. The terminology of the description is specific and follows a conventional protocol (Schoeneberger et al., 2002). Because this protocol is standard, a soil scientist as well as a non-soil scientist can read and understand the profile description without actually seeing the soil itself. Properly describing a profile requires much practice and training. Training can be obtained at many universities and through continuing education. One additional source of training materials is the Model Decentralized Wastewater Practitioner Curriculum (Lindbo and Deal, 2005). This curriculum, developed for onsite wastewater professionals, provides detailed PowerPoint presentations full of visuals that can be used for basic training in soil profile description.

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