A "Brief" Supplement on Characterizing Soil Profiles

Logan Peterson—NM Envirothon

A very important skill for any soil scientist is the ability to characterize a soil profile. You will be expected perform many of the tasks involved during the Soils Exam. This guide was designed to supplement the "Soil Characterization" document, which you should read first.

During the exam, you should find a nicely-excavated soil profile. If you don't, you are being cheated, and should complain loudly. If you want to practice on your own soil, please make sure that you have permission to dig, and call 811 at least 2 days beforehand to make sure you aren't going to hit gas lines or other underground utilities. An easier option is to find a cut along a road or arroyo, or a hole that someone else already dug.

Soil Horizons

The material below is meant to supplement pages 2-6 of "From the Surface Down", which you should read first.

Horizons can be distinguished by differences in soil properties such as color, texture, structure, pH, electrical conductivity, or the accumulation of carbonates. The breaks between horizons are not always distinct. Often, soil properties will very gradually change with depth. Thus, no two soil scientists will distinguish a soil's horizons in exactly the same way. One scientist might identify 8 horizons in a pedon, while another might only identify 4. One might consider the A horizon to be 16 cm thick, the other might consider it to be 20 cm thick. As long as they are both identifying important soil properties, neither of them is necessarily wrong. Examples of how this might be done appear below.

Start at the surface. Is there a layer of dark, decomposing organic matter or *duff*? We would call this an **<u>O horizon—</u>**the only horizon that is mostly organic matter. O horizons are most common in forested settings and wetlands. Organic soil materials are very low in density. If you try to hand-texture them, they will not feel sticky or gritty because they lack clay and sand (mineral materials). Since true soil must be unconsolidated, intact leaves, needles, and roots aren't soil…but they will become soil after critters have chewed them up.

Regardless of where a soil is located in NM, it probably has an **<u>A horizon</u>**; beginning either at the surface, or directly below the O horizon. A horizons are mineral layers that are characterized by an accumulation of decomposed organic matter. They should be at least slightly darker or browner than the horizons below, and it should have a higher concentration of fine and very fine roots (see page 2-71 of the "Field Book for Describing and Sampling Soils"). A horizons usually have weaker (lower grade) structure and often have smaller aggregates than B horizons below. In Rocky Mountain grasslands, and in the High Plains of northeastern NM, soils often have thick, dark A horizons. Desert soils often have thin A horizons that are only slightly darker than the rest of the soil profile. Forest soils often have thin A horizons directly beneath the O horizons.

E horizons are common in wet forested areas, but are rare in most of NM. They usually appear directly below A and/or O horizons. They are mineral layers that are characterized by the removal of clay and/or organic matter. E horizons are generally lighter in color, and often contain less clay, than the horizons below. Many of New Mexico's soils have B horizons that could be mistaken for E horizons because they are light in color due to calcium carbonate accumulation. These B horizons will fizz when exposed to acid, so a squirt of hydrochloric acid (HCl) or vinegar will allow you to distinguish them from E horizons.

The **B horizon** either occurs directly below the E horizon, or directly below the A horizon if there is no E. They are mineral layers that are characterized by the addition of materials—such as clay or calcium carbonate—which were leached out of horizons above by percolating water. B horizons usually have stronger (higher grade) structure than the horizons above. In older soils, B horizons often have more clay than the horizons above. B horizons with accumulations of iron oxide clays are often red in color. In drier environments, B horizons often contain accumulations of calcium carbonate, which has been *leached* from the horizons above. Younger soils, such as those that occur on *floodplains*, often lack B horizons, and may have a C or R horizon directly beneath the A. The youngest soils do not contain B horizons.

The **C horizon** consists of *parent material* which hasn't been greatly altered by soil-forming processes. You'll either find it at the bottom of a profile (if your hole is deep enough) or directly above an R horizon. C horizons generally have no real soil structure (although they may break apart into clods when dug, or they may consist of decomposing rock fragments). C horizons also don't tend to have much organic matter or visible accumulations of carbonates.

R horizons consist of hard bedrock. This material may have some cracks which contain some soil material, but they are mostly impermeable to roots. R horizons are also highly impermeable to water, leading to poor drainage in wetter areas. Technically, an R horizon is not soil, since it is consolidated (not broken-down). Since digging through an R horizon usually requires a jackhammer or dynamite, I don't have any good pictures of one.

Figure 1. An O horizon at the surface of a forest soil in Northern Montana. On the right is some material that I sampled from this layer. This material is pretty fresh, but it has been decomposed enough to classify as soil. It felt very light in my hand, and would not form a ribbon when I tried to hand-texture it. Photos by Logan Peterson.

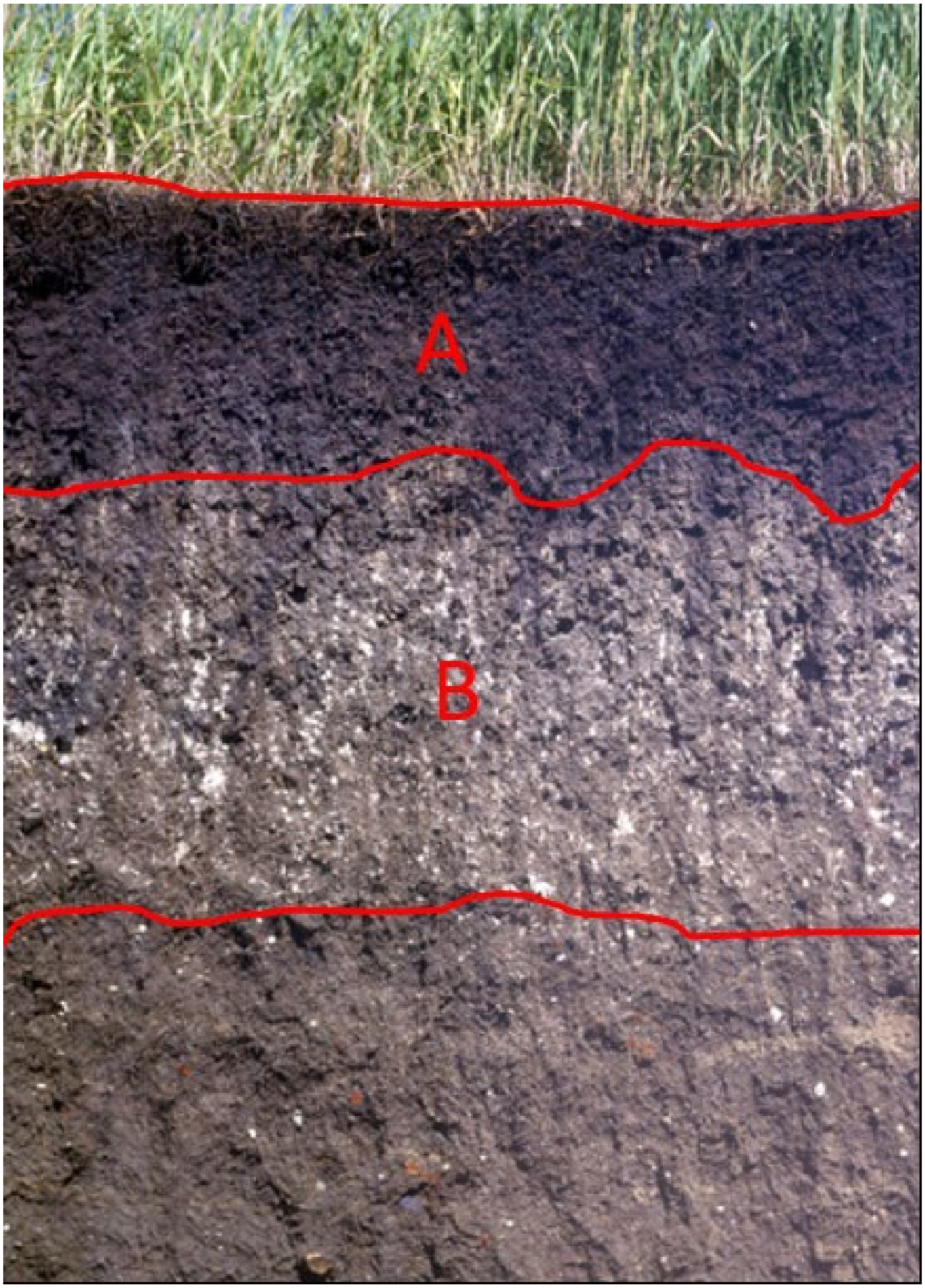

Figure 2. A grassland soil from somewhere in the Midwest…perhaps Nebraska. The A horizon at the top is darkened by decomposed organic matter (humus), but it is mostly mineral material. The B horizon is lighter in color because it is lower in organic matter, and contains accumulations of calcium carbonate (the white spots). If you sampled this B horizon, you'd find that it has blocky structure. If the bottom layer lacks soil structure, we'd call it a C horizon. If it has structure, we'd call it another B horizon Source: nrcs.usda.gov

Figure 3. Two soil profiles with C horizons at the bottom. On the left is a soil in the Sangre De Cristo Mountains in NM. The A horizon is slightly darker than the layers below. The B horizon has subangular blocky structure, and has much more clay than the A or the C. The C horizon is composed of soft shale bedrock; it breaks up into flat chips—a shape inherited from the bedrock, and not from soil-forming processes. Note that I am measuring depth correctly: from the top-down. On the right is a young soil (maybe only a few hundred years old) in Carlsbad Caverns National Park. It's a horizon has soil structure is darker than the C below. The C horizon has no structure, and is basically just a pile of loose sand and gravel. Note that the rock fragments are rounded—indicating that they were carried quite a distance and deposited by water (so the parent material type is alluvium). Photos by Logan Peterson.

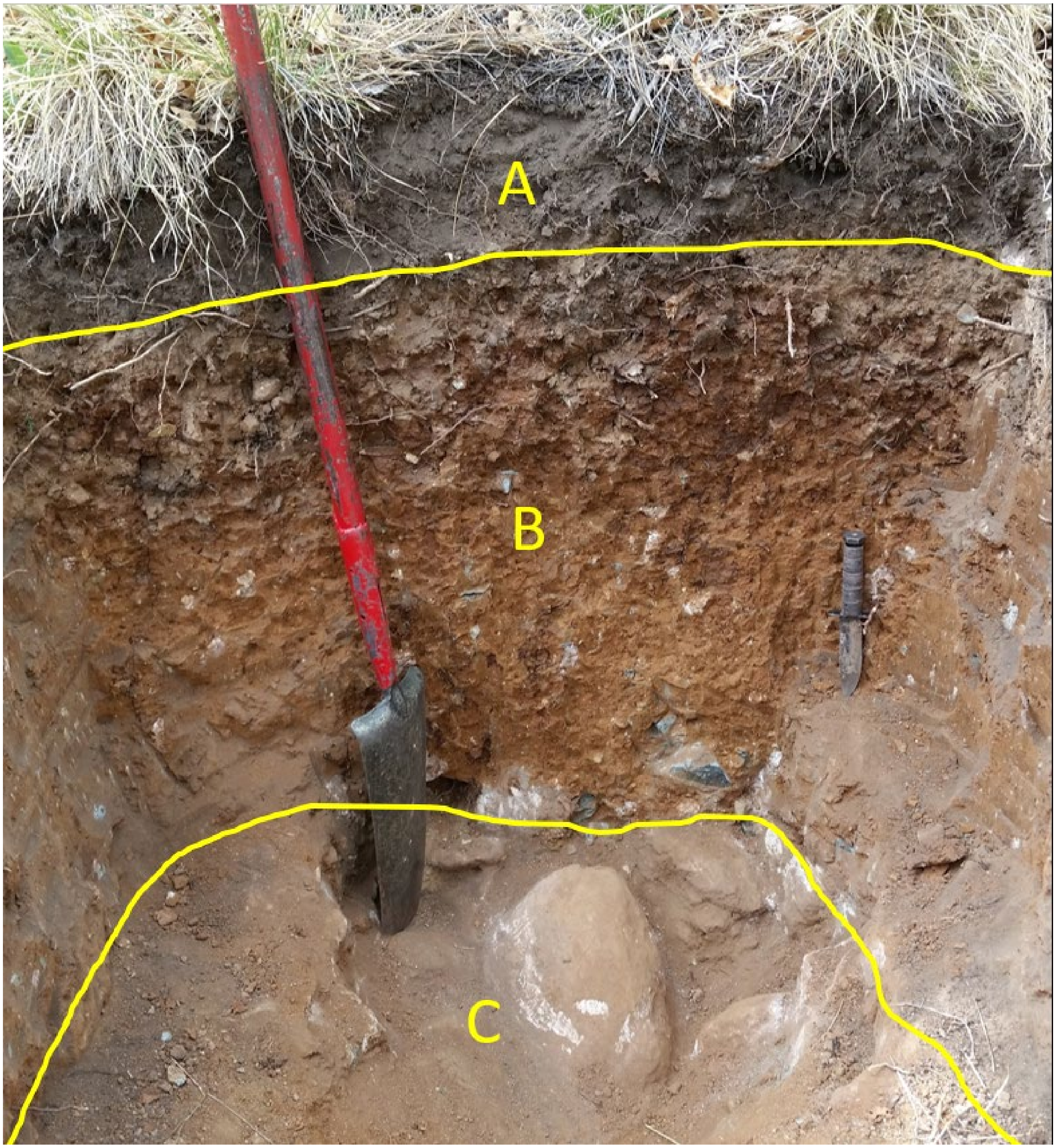

Figure 4. A Soil profile from a previous NM Envirothon! There was a very thin O horizon at the surface—about 1 cm thick. Below this was a very obvious A horizon—if you hand-textured it, it would have made a ribbon and felt gritty. Below this is a thick B horizon that is quite high in clay—it felt very sticky and formed a long ribbon. At the bottom is a C horizon (no structure)—essentially a pile of large, rounded stones with some fine earth in-between. Call me lazy, but I'd been digging for 4 hours by the time I got to this layer, so I stopped there. Photo by Logan Peterson.

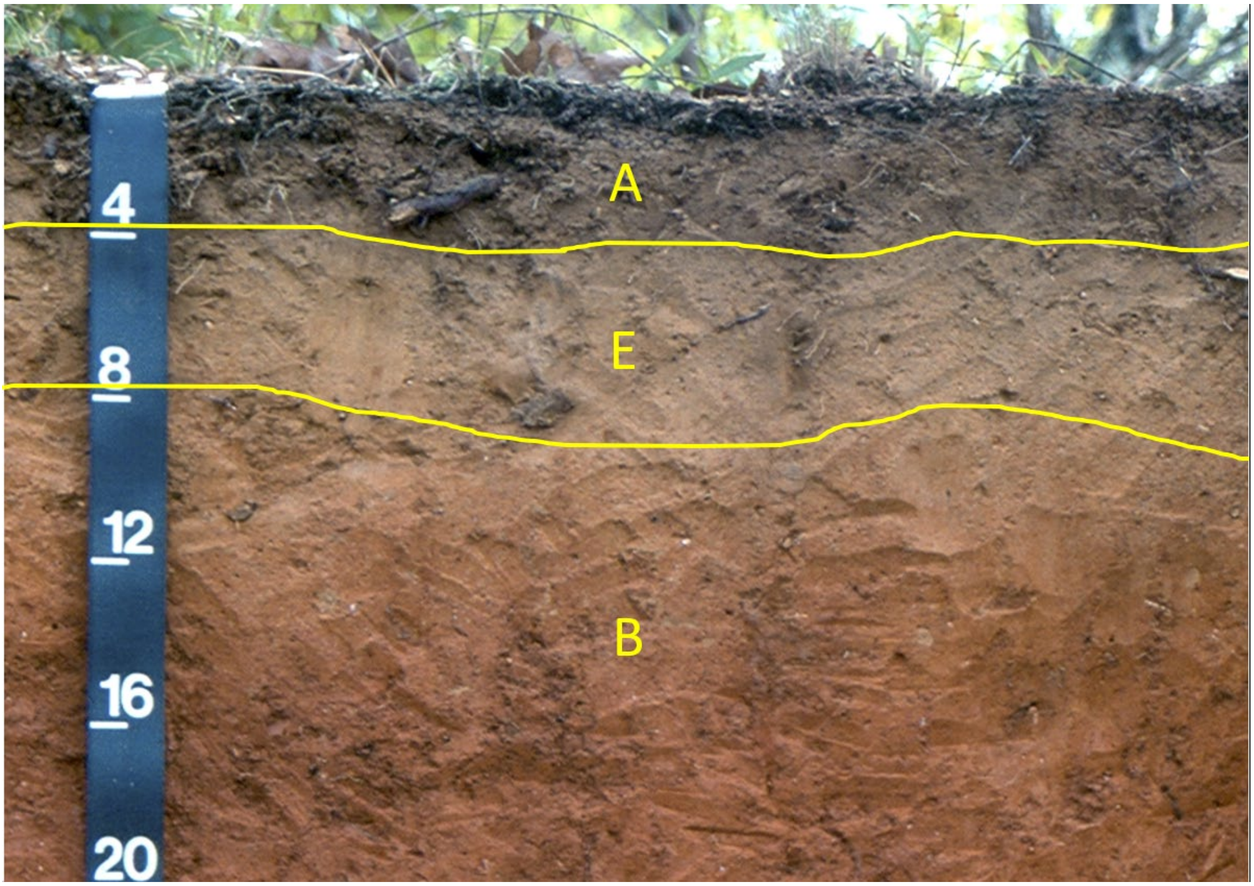

Figure 5. A forest soil from the Southeastern US. The E horizon is lighter in color than the A or the B. Over thousands of years, percolating rainwater has washed clay particles out of the A and the E into the B horizon below. We do find E horizons like this one in old soils in the mountains of NM, but they are rare enough that I don't have a good photo of one. Source: nrcs.usda.gov

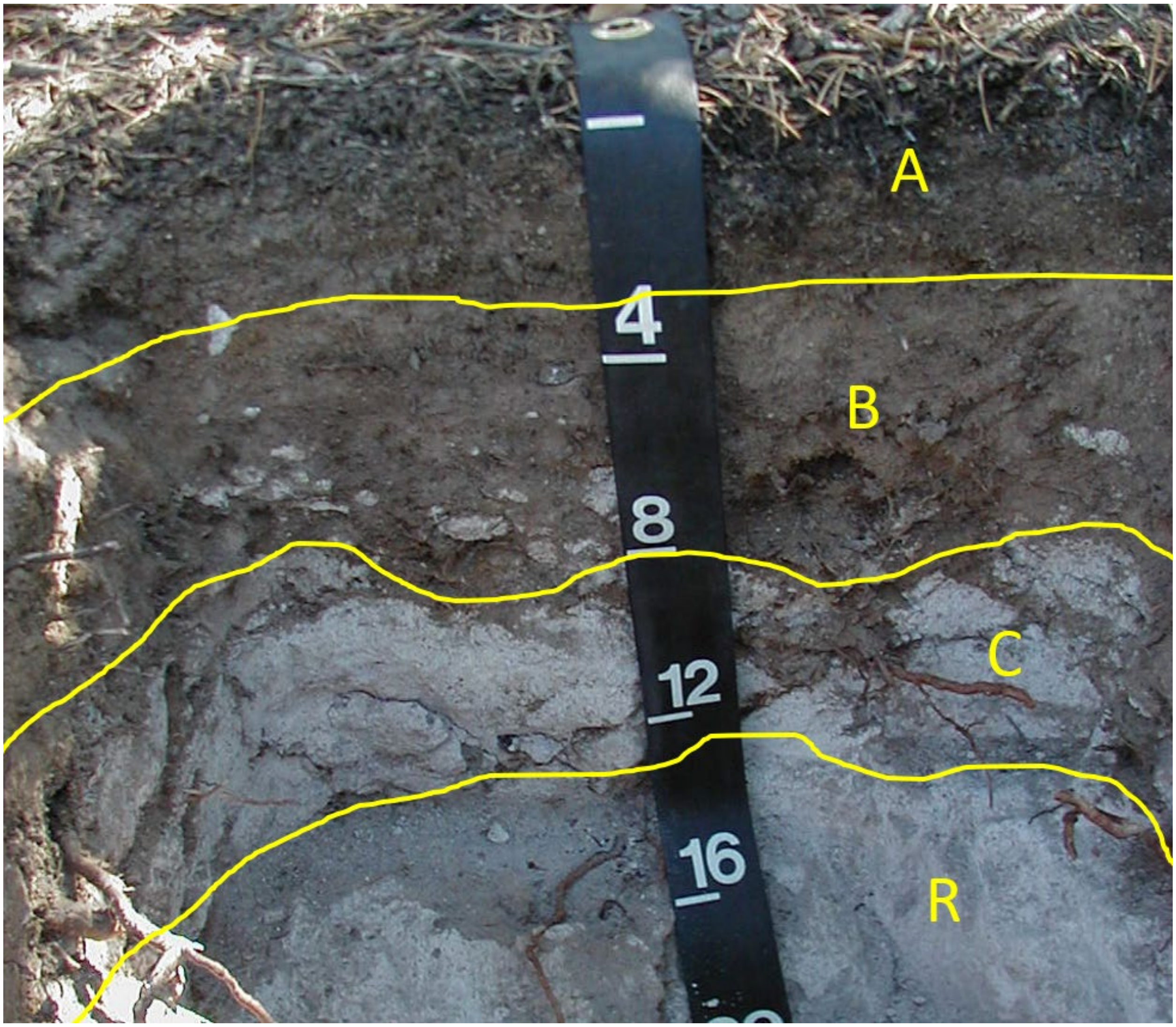

Figure 6. A soil profile from Bandelier National Monument, NM. Tape is in inches. Parent material here is residuum weathered from tuff (welded volcanic ash). The C horizon here is soft bedrock (note the roots and many cracks). The R horizon is solid bedrock that was very difficult to dig through. There is probably a very thin O horizon at the surface (< 1 cm thick), which many soil scientists would ignore. Photo by Charles Hibner.

Flowchart for Characterizing Soil Horizons

Composed of intact plant structures (i.e. pine needles)? YES ⇒ Not soil…yet. Look deeper.

NO ⇓

Layer of decomposed organic material? YES ⇒ O horizon

NO ⇓

Mineral soil layer, near or at the surface, that has been darkened by decomposed organic matter? (Usually darker than the layer below it). YES ⇒ A horizon

NO ⇓

Mineral soil layer, near or at the surface, that isn't darkened by decomposed organic matter? (Usually lighter and lower in clay than the layer below it). YES ⇒ E horizon

NO ⇓

Mineral soil layer, below the surface, that has soil structure? (B horizons often have more clay and/or calcium carbonate than the horizons above). YES ⇒ B horizon

NO ⇓

Mineral soil layer, below the surface, that lacks soil structure? (Can be sediment or soft bedrock) YES ⇒ C horizon

NO ⇓

Hard bedrock? YES ⇒ R horizon

Table for Identifying Soil Horizons

Horizon	Mostly organic matter?	Darkened by organic matter?	Has real soil structure? (not structure from bedrock)	Consolidated? (i.e. not decomposed)	Accumulation of clay?	Accumulation of carbonates?
O	yes	yes	no	no	no	no

A	no	yes	usually	no	no	no
E	no	no	sometimes	no	no	no
B	no	sometimes	yes	no	yes	yes
C	no	sometimes	no	no	no	sometimes
R	no	no	no	yes	no	no

Characterizing Soil Properties

Once we have divided a profile into horizons, our next step is to analyze each of these layers. Refer to our "Soil Characterization" guide for some basic information on how to determine a soil's structure, color, and consistence. Note that soil scientists usually record color and consistence for moist and dry samples, so analyze dry peds as well if possible. You'll be given a Munsell Soil Color chart to use during the test. "Soil Characterization" does a good job of covering structure type, but you should also refer to pages 2-55 to 2-62 of the "Field Book for Describing and Sampling Soils" for guidance on the *grade* and *size* of *aggregates*.

The single most important soil property is *texture*; you'll notice that it comes up throughout your soil guides. With some practice, you can learn to determine soil texture in the field by playing with a wetted sample. Before you begin, make sure to remove all fragments of rocks or plant matter that are larger than 2 mm; a 2 mm soil sieve is helpful, but you can also pick out rocks by hand. As a rule of thumb, sand will make a soil feel gritty, silt will make a soil feel buttery, and clay will make a soil feel sticky and cohesive. Refer to the "Texture Guide" and to pages 2-36 to 2-45 of the "Field Book for Describing and Sampling Soils". Also, watch the following videos. The first is excellent, even though it lacks audio.

http://www.youtube.com/watch?v=GWZwbVJCNec
http://www.youtube.com/watch?v=IOyaBxj767s
http://www.youtube.com/watch?v=W0osjN0t-Ho

Other soil properties that soil scientists routinely analyze in the field are pH, EC, the kinds and concentrations of roots, percentages of different types of rock fragments, and concentrations of carbonates.

Soil pH (AKA "reaction") is a measure of how acidic or alkaline the soil solution is. pH plays a critical role in the availability of nutrients to plants. Most nutrients are quite available at neutral pH values, but many are unavailable towards either extreme.

You may be provided with a pH meter during the soils exam. If so, here's how to measure soil pH: put 10 to 20 mL of sieved soil in a small cup or beaker. Add enough water so that the total volume in the container is twice that of the soil sample (e.g. if you started with 15 mL of soil, add water to the 30 mL mark. Stir the slurry and let it sit for as long as possible. Turn on the meter and submerge the glass probe. Wait for the reading to stabilize, and record it. Refer to the Chemical Response section (2-85) of the Field Book to determine which class (i.e. Moderately Alkaline) a sample falls into.

EC, or electrical conductivity, measures a soil solution's ability to carry an electrical current. Salts ionize in soil solutions, and these ions carry charge. Thus, EC is a convenient way of measuring the amount of soluble salt in a soil sample. Most plants are adversely-affected by high levels of soluble salts, which impede their ability to absorb water and many nutrients.

EC is measured in much the same way that pH is. If you're provided with an EC meter, perform the same procedure described above.

Plant roots can tell us a great deal about a soil profile. For example, if nearly all roots are concentrated at the soil surface, we can conclude that the sub-soil is inhospitable to roots for some reason. Maybe it's been highly compacted by machinery, and roots just can't penetrate it. Maybe the subsoil is full of soluble salts, or has an extreme pH value. Maybe the sub-soil is often saturated, so that roots cannot breathe.

Soil scientists categorize plant roots by size classes. If you're asked about these size-classes, refer to the Roots/Pores section (2-70) of the Field Guide.

Soil scientists consider any piece of mineral material greater than 2 mm across to be a rock fragment. Rock fragments in a soil horizon can affect the way it behaves. Large fragments can damage machinery, and make excavation expensive and tillage (plowing) impossible. Fragments are also important because they represent volume that does not provide much water or nutrients to roots. Soils that are full of rocks have lower water-holding capacities than those composed entirely of fine-earth (< 2 mm). If a horizon is 60% fragments, then roots can only use 40% of its volume.

You can estimate the percentage of volume occupied by rock fragments by running the soil through a 2 mm sieve. Once you've separated the fine earth from the fragments, simply compare volumes. For example, if I have a small pile of fragments and a large pile of fine earth, I subdivide the fine earth into a number of piles the same size as the fragment pile. Let's say I have 4 fine earth piles and one fragment pile…all of roughly equivalent sizes. The fragments represent $1/5^{th}$ of the total volume, or 20%.

Carbonates, such as calcium carbonate ($CaC0_3$) and magnesium carbonate ($MgC0_3$) are quite common in the soils of arid and semi-arid regions (i.e. most of NM). Although they are not highly soluble, they are salts, and can dissociate into ions ($CaC0_3 \rightarrow Ca^{2+}, C0_3^{2-}$) in solution. For this reason, carbonates are often leached out of surface horizons by percolating water. When plant roots suck water from sub-surface horizons, carbonates can precipitate out of the soil solution, leaving white concentrations. The carbonate ion acts as a base in soil solutions ($C0_3^{2-} + H_2O \rightarrow HC0_3^{2-} + OH^-$), so carbonates raise soil pH. Many nutrients are less available to plants at high pH, so soils that are rich in carbonates are often less fertile.

If you suspect that carbonates are present in a horizon, you can do a simple field-test. Put on some goggles and squirt some acid (I use dilute HCl, but vinegar works as well) onto the soil sample. The soil will effervesce (fizz) if carbonates are present. [$C0_3^{2-} + 2H^+ \rightarrow H_2O + CO_2(g)$] .