The Pleasures of Soil Watching

by Francis D. Hole

Soil is the vital substance that supports life on land. Because it usually feels stable under foot, we call soil *terra firma* but when we become aware of the vibrational motions of water molecules and films, of air, roots, and organisms in soil, we are more inclined to call it *terra vibrata*. When storm winds bend trees, for example, the soil "dances" measurably as roots are jerked this way and that. Soil endures, both firmly and in a lively manner, wherever it is well protected by a covering of vegetation and associated natural mulch or litter. The soil supports plants; plants protect the soil. It is a cooperative enterprise, which flourishes in great forests and grasslands, as well as in well-managed farms, rangelands, and gardens.

The pleasures of soil watching can match those of birding. Among the chief differences are that we soil observers look down more than up, and that soil does not migrate seasonally as birds do, nor does it move about the local landscape (accelerated erosion excepted). We do the moving, from soil to soil. Landscapes are natural jigsaw puzzles composed of contrasting soil bodies interspersed with bodies of water and rock outcrops.

The 1980s would be a logical decade in which to organize a Society of Amateur Soil Observers. The science of soil, called pedology (from the Greek for ground, *pedon)*, was founded simultaneously in America and Russia in the 1880s. So a centennial celebration is in order. Picture city and country people alike, fanning out over a landscape (assuming that landowners have granted permission) in orderly fashion, studying soil patterns in honor of the 100th birthday of the science of soil.

As part of our celebration, we should salute a German-American professor, E. W. Hilgard (1833-1916) who in a scholarly cotton census published by the U.S. government in the 1880s, presented an early scientific treatise on soils. We should also applaud a progressive Russian natural scientist, V.V. Dokuchaev (1846-1903), who in 1883 published a remarkable work on the Russian *chernozem,* which was a peasant term, now used by scientists in a technical sense, for the productive "black land" of the steppes. chaev used letters of the alphabet, A, B, C, to designate the natural soil layers, called horizons, from the top down. Today, a century later, thousands of soil specialists around the globe use concepts and methods established by Hilgard and Dokuchaev for observing, analyzing, classifying, and managing soils. It is a propitious moment for the ascent of the soil watcher into the constellation of friends and defenders of landscapes, wild and tamed.

Most of us need some instruction in how to encounter soil, aside from the all-important, intimate contact with surface soil in gardening and farming. A natural soil body extends on down many feet, the full length of plant roots. This short article is an introduction to the subject of "soil watching," not just of the surface soil, but of entire bodies of soil, in their dark and silent depths. These deep reaches of soil become known to us through pictures and samples. Once we are armed with the necessary information about what to look for in the way of soil profiles and their constituent horizons, and how to go about it, we can join the ranks of active amateur soil observers. To start with, our focus is not on serious problems of abuse by human beings. Rather, we will simply allow ourselves to enjoy the vital kingdom beneath our feet. If we become friends of the soil first, we will be better able to act in its defense later.

Soil, though out of sight, need not be out of mind. Until our death we remain exiled and liberated from the soil, but we draw on it for nutrients-phosphorus, calcium, potassium, etc.-as long as we live. The soil is, both literally and figuratively, the root domain.

It has taken millions of years for enormous quantities of solid, seemingly unyielding granite and related rocks to be transformed into the particulate soil. The spaces between soil particles make room for water, air, roots, and animals that the rocks in their density would not accept. We can be grateful that the continents no longer present to the sun rock surfaces extending relentlessly from shore to shore. We would go hungry in such a barren wasteland. Fortunately, the soil is there for us and serves as our welcome mat to life on land, whose inhospitable core is safely submerged under a nearly continuous blanket of loam.

The word "loam" connotes a mixture of sand, silt, clay, and humus, with or without pebbles and stones. The first three terms-sand, silt, clay-stand, respectively, for (1) coarse mineral grains (sand particles are 2 to 0.05 millimeters, or 1/12 to 1/500th inch, in diameter), which feel gritty when rubbed between the fingers; (2) medium-fine particles (silt grains are 0.05 to 0.002 mm in diameter), which feel like flour; and (3) very fine particles (clay particles are less than 0.002 mm in diameter), which feel sticky when wet. Humus is decomposed vegetable and animal matter,

which gives soils their black, dark gray, and dark brown colors and endows them with greater capacity to support plant growth.

Rock has come a long way to reach its powdery state in the soil. Visualize a cubic foot of granite. It has six sides for a total of six square feet of surface area. Nearly all of the 175 pounds of tightly interlocked mineral grains are isolated from the environment, waiting to be set free by slow processes of disintegration. Once the rock is finally reduced to soil, the approximately three million sand-size grains of minerals that made up the rock separate, and many of them break down into still finer sand, silt, and clay particles. We should not be surprised that 1,000 grains of sand are in a single gram of sand (about the volume of a pencil eraser); 6 million particles of silt are in a gram of dry silt; and 90 billion particles of clay are in a gram of dry clay. Imagine that 175-pound mass of granite converted to dust (sand, silt, clay) and mixed with humus. It is now soil and has increased twofold in volume to two cubic feet, because of added pore space. The total surface area of the billions of particles now equals one square mile, or nearly 28 million square feet. No wonder that the soil acts like a sponge, as it takes up water and stores nutrients in forms available to plant roots.

In most soils of this planet, these four kinds of particles-sand, silt, clay, humus-are intermixed. In fact, they are likely to cluster together in pea-shaped and block-shaped units, called peds (about an inch in diameter, to a tenth of that size). Soil scientists sound like architects and geometry teachers when they describe shapes and arrangements of soil peds in the ground: granules (pea-shaped), blocks, prisms, plates (fragile wafers of soil). These various building units of soil are shaped by earthworms, moles, wasps, spiders; by growing roots; and by swelling and shrinking as soil becomes wet and then dries, freezes and thaws.

We can become familiar with this world of peds and particles by examining exposures (river banks; newly scraped roadsides) and samples pulled out of the ground by means of special tools. Imagine a plug out of a watermelon that shows green, white, and red layers (horizons). The plug is a model of a soil pedon, a column of soil in which the horizons are all exposed to view: topsoil, subsoil, and parent material, commonly to a depth of many feet. A single face (two-dimensional) of a pedon is called a soil profile or sequence of horizons. Each of the hundreds of thousands of kinds of soil on the planet has a unique profile.

Now let us consider the nutrient chain, from rock to soil to plant to food to human beings. Calcium, for instance, from feldspar grains of granite, or from derived limestone, becomes available through soil formation to plants, which take up the calcium into underground parts, then into leaves, seeds, and fruits, which we eat directly, or which cows and other animals eat for us. An incredibly complex array of elements and compounds flows in balanced fashion into our bodies along the nutrient chain. We are what we eat. In a sense we are unique, moist packages of animated soil.

Here I would like to take time out from our carefree exploration of the world of soil to discuss a life and death matter. For hundreds of millions of years, life forms, human beings among them, have evolved in a rich and proportioned environment of elements and compounds. The adequacy of that milieu is increasingly threatened in two ways (as has been summarized recently by National Academy of Sciences member M. L. Jackson, working with C. H. Lim). First, "trace" elements, which are those needed in human diet in very minute amounts, are now deficient in intensely farmed soils. Soils of China, for example, are generally exhausted of the trace element selenium. So also are soils of many agricultural areas of New Zealand and the United States. Second, industrialization has introduced into soils certain substances that are dangerous contaminants when taken into the human body. These substances include the heavy metals lead, mercury, and cadmium; organic toxins; and radioactive elements-all of which are accumulating in soils. Some trace elements help the body to cope with these contaminants. Data indicate that selenium, copper, and zinc, for example, in appropriate daily amounts help to protect a person against cancer and other disorders fostered by ingestion of heavy metals. Such supplementary trace

Soil profiles in Ellsworth County, Kansas (overleaf).

Diagram of a road bank an which the layers (horizons) of a soil are exposed as a complete "soil profile." The close-up view is of a column of soil, called a pedon, the front face of which is the profile consisting of A, E, Bt and C horizons over rock (R). The topsoil consists of dark horizon (A) over pale horizon (E). The subsoil (B horizon) has a "t" symbol that stands for clay (Ton, in German), because of clay accumulation there. The C horizon is loose parent material that has not yet changed into true soil.

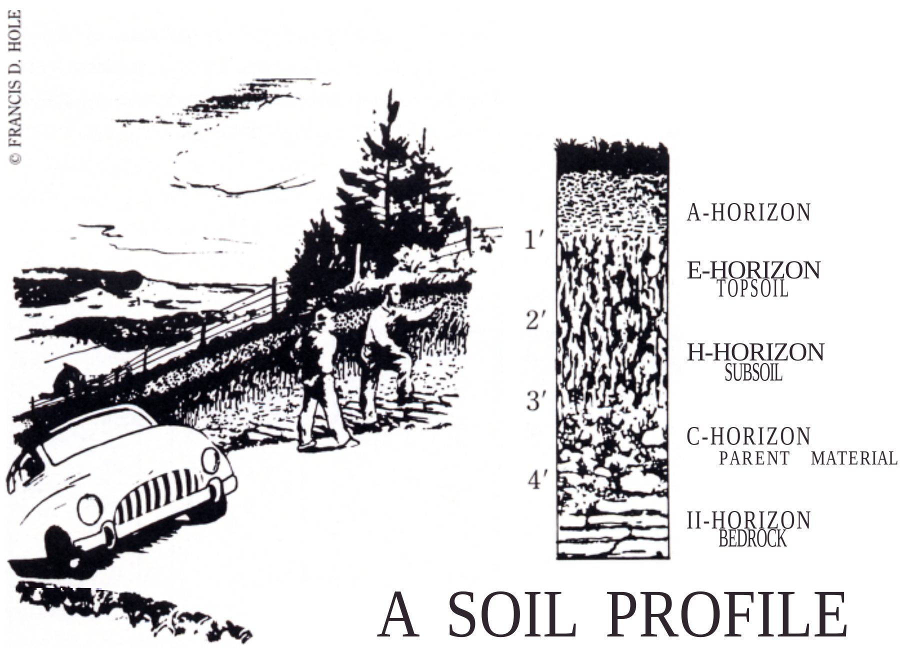
ments may prove to be as important in human diets as iodine in table salt.

We are fortunate if we have access to food produced from fertile soils of alluvium, glacial drift, and volcanic deposits. In contrast to such soils, some little-weathered sandy soils and very old soils of highly leached, red equatorial lands under intensive cultivation do not generally support crops that provide all the elements required for human nutrition. An African woman in one of my classes on soils of the world once told me that in her region it was the custom for pregnant women to eat some soil from abandoned termite mounds, in which the insects had stored calcium and other nutrients.

But our main purpose in this essay is to learn to take pleasure in the soil. I recommend that we take a soil walk. We shall give ourselves two assignments, namely to observe what goes into soil and what comes out.

Let us start in the countryside, where we obtain permission in advance from the landowner to probe the soil. The list of things that enter the soil daily is an impressive one, rivaling bird lists in length. Anyone who has walked through a maple forest is familiar with the tufts of leaves, twisted into burrows the size of one's little finger: these tufts are called earthworm middens. Dead leaves like these are among the natural debris that is pulled into the soil by various agents. Water and air also enter the soil. While standing in a rainstorm, one can observe water soaking into the soil, most abundantly at the base of a smooth-barked tree, where stem flow increases the volume. I have heard soft, hissing sounds as bubbles of air escaped from a pasture soil during a summer downpour. Air goes in, and it also goes out of the soil, with the passage of overhead high- and low-pressure air masses. It is as if the soil breathed. (Yet soil air is kept relatively low in content of oxygen and high in proportion of carbon dioxide, as a result of the metabolism of soil organisms.) Animals transport material to the surface: some earthworms bring up globules of soil, which lie strewn over the ground like pellets of "black gold"; these are called earthworm casts. Ants are worth watching, too. They help build topsoil in forests of New England, and even work through cracks in sidewalks in cities. And aside from fauna1 activity, the soil is restless on its own, as evidenced by the cracking of soil into polygons in dry seasons, and the closing of the cracks again when rains come.

To monitor the constant change in microenvironments at the surface of the ground a soil watcher might use a row of flat-headed nails, set two inches apart and thrust into the moist earth with heads flush with the ground surface at the start of the growing season. Sets of these nails can be placed at contrasting sites, accessible to weekly or biweekly checking, but protected from traffic, human or otherwise. A witness stake with colored ribbon can mark the location of each row of nails, and a template consisting of a strip of wood penetrated by a row of small nails spaced exactly the same as the nails in the soil can be used to locate the heads of the soil nails at each inspection. The point is to record what has happened to each nail since the last observation. Has it been buried? Under what? Sandy soil? Moss? Dead leaves? Worm casts? An ant mound? A butterfly wing? Or has the nail head been completely exposed



A SOIL PROFILE

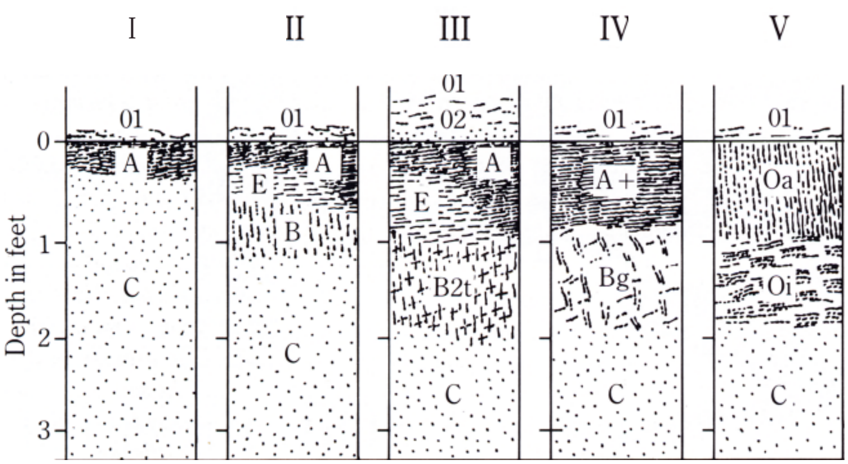
by soil erosion that leaves the nail standing like a spine? Or did frost push the nail up? Or a mole? Questions are to be enjoyed and pondered, even if not answered at the moment. Who can comprehend the ways of the soil? Nobody can do this entirely. Who can enjoy the process of soil watching? We can, certainly.

If we walk in a forest dominated by trees more than 100 feet tall, we might wonder what kind of soil supports such an impressive stand. We may dig a pit to expose the profile of the "true" soil (down to the base of the B horizon, at three feet, for example), that usually overlies many more feet of the parent material (C horizon). The soil horizons in a forest soil can be striking: black over pale lavender over dark brown, grading downward to yellow-brown. Organic matter accumulates as dead leaves and pine needles on the surface. Also, fine humus gradually washes down to darken the subsoil, leaving a bleached horizon (called the E horizon) above, where organic acids have stripped away color coatings from quartz particles. What happens to this soil when the forest is cut and crops replace trees? The color patterns become simplified, as the original horizons are blended by cultivation. The great diversity of biota in the original wild soil is curtailed.

Some soil walkers collect specimens of soil-earthworm middens and casts, peds of various sizes and shapes, miniature soil profiles made by gluing pinches of soil from various horizons onto cardboard strips-and carry them in egg cartons back to the garage shelf to keep company with empty wasps' nests and interesting stones. I know someone who, by pressing sticky paper against the forest floor, mounts collages of earthworm casts, lacy dead leaves, and other debris to set in the house beside flower bouquets as something of comparable beauty!

If we live in a city, a soil walk lets us observe interactions between soil and the works of humankind. It is not unusual, in a corner of a city park, to see a gravel path or paved walkway partially overtopped by what I call creeping soil, which bears a protective coat of grass with it. The soil may manage to cover half of the pavement or path in places, as instability of the soil underneath dismembers the walkway from below. If the crew of park workers is too busy to take action, the trespass of the soil may continue uninterrupted. The soil is a slow-motion sea that gradually devours whatever it can-fence posts, gravel paths, dead trees, decaying buildings. Maintaining a city in the face of this motion is work.

think it is important for us human beings, who are people of the light, to surround ourselves with images of the creative realm of darkness, the supporting soil on which we tread. There is no way that we can be exposed to such images naturally, on a regular basis, as we are to those of sky, birds, vegetation, and a variety of animal forms. Several possibilities come to mind. I have already mentioned the mounting of "soil bouquets," that is, collages of delicate earthworm casts and circular ant mounds. The art of soil-bouquet arrangement is in its infancy, as a result of our habit of ignoring the soil as a universe of beauty. Soil jewelry is, as far as I know, not a lost art, but rather an undiscovered one. Nature lovers of all ages have surprised me with the attractive creations they have made on soil walks with me, by pressing soils of different colors into acorn cups, with appropriate adhesives. Lengths of cord can be glued to the back of the cups, which then are affixed to clothing: conversation pieces! Home interior decoration with soil patterns is another practical means of giving us daily acquaintance with the hidden lacery beneath our feet. Framed enlargements in color of views of natural soil



Some common kinds of soil profiles (below). Soils I, II, and III constitute an age sequence from a very young soil (I) to a "mature" one (III), all on upland. Soils IV and V are wetland soils. Four (IV) is composed largely of rock particles. Humus has accumulated in the A horizon, which has received deposits (+) from the upland by erosion. The subsoil of IV is bluish-grey (g) in color. Five (V) is a muck, composed mostly of organic matter (O) or humus, which is aged (a) near the top, and fibrous (i) below.

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as seen through a petrographic microscope complement more familiar pictures of flowers and landscapes.

Exhibits of soils are notably scarce in museums. I recently saw in the natural history museum in Victoria, British Columbia, a spectacular enlargement of a porous block of soil, in which an earthworm appeared as large as an elephant's trunk. I am particularly pleased with the idea of dioramas of large soil pits, complete with forest or grassland vegetation rooted in the soil, representing different parts of the world. Miniature dioramas are effective and less expensive than full-scale ones.

The soil has more to say to us each day than we are capable of receiving and finding words for. Eskimos have many words for snow because they are attentive to it. We have few words for soil as an entity. Our vocabulary for communicating about soil is embryonic. Walt Whitman recognized this when he wrote:

The press of my foot to the earth springs a hundred affections.
They scorn the best I can do to relate them

With the coming of age of the young science of soil, pedology, we are in a better position than the poet to speak for and about the soil, however less eloquent we may be. Thanks to a voluminous scientific literature about soils published worldwide in the past century, we in the 1980s are able to understand this natural resource better than ever before. The soil needs all the friends it can get, friends who practice the art of soil watching, with pleasure.

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Professional soil scientists examining the horizons (layers) of a 10, 000-year-old forest soil, as exposed in a ditch bank beside a highway (above). These workers are classifying the soil in a world soil-classification scheme. They will assign ratings to the soil for numerous possible uses of it, ranging from wildlife habitat to urban development. The soil will be designated by the name of a local settlement.