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Diagnostic Soil Horizons in Soil Taxonomy

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This paper discusses the major kinds of soil horizons, their use in Soil Taxonomy, and their significance in engineering soil behavior. The characteristics of the soil in any place are a result of the combined influence of climate and living organisms on a specific kind of parent soil material, conditioned by relief, over a period of time. The combined effect of these factors is reflected in most soils as soil horizons of unique kinds. The presence or absence of kinds of soil horizons is an important criterion in the definition of classes in Soil Taxonomy. Each key soil horizon has a unique morphology that reflects its genesis and composition and a unique behavior due to its properties. Some soil horizons have accumulated clays, organic matter, or iron and other minerals. Other soil horizons have lost such materials. In the classification and mapping of soils, the pedologist studies the properties of each soil horizon in situ and, on the basis of this study, selects sites for obtaining samples of soils for characterization in the laboratory.

The diagnostic soil horizons more commonly referred to as the A, B, or C horizons are used as the building blocks of the soil classification system. They reflect soil weathering processes and are the result of the combined influence of climate and animal and plant organisms on a specific kind of soil parent material. Soil Taxonomy includes those inherent soil characteristics that affect plant root-soil relations and soil-engineering relations. J. S. Mill (1) wrote that the useful classification is one that uses the properties of constituent objects chosen to identify groups that are causes of, or at least sure marks of, many other properties. Soil horizons are the marks of many other properties. They are the link between Soil Taxonomy and soil genesis.

A soil horizon is defined as a layer that is approximately parallel to the soil surface. It has some sets of properties that have been produced by soil-forming processes, and it has some properties that are not like those of the layer just above or beneath it (2). Soil horizons are the marks that now exist in the soil that indicate the genesis of the natural soil. For example, a soil with an argillic horizon indicates a soil formed under a climate that enhanced rock weathering, leaching of the base, and a downward movement of clays.

The objective of this paper is to define some of the key soil horizons, explain their role in Soil Taxonomy, and relate their significance to engineering soil behavior.

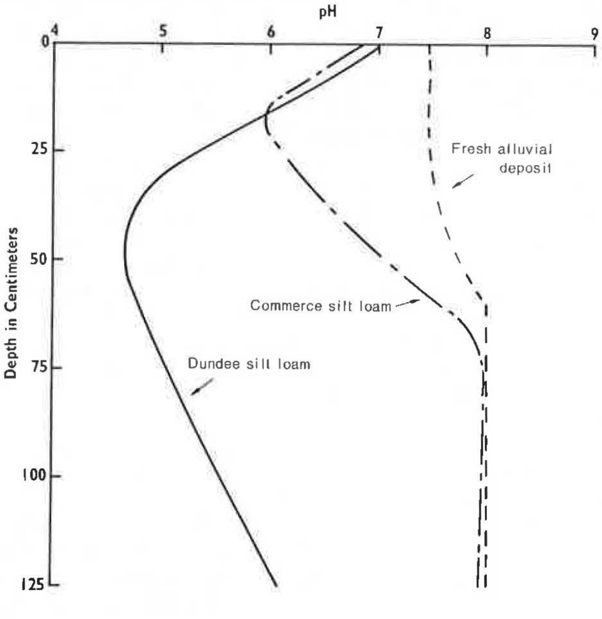
INTERPRETATIONS USING SOIL TAXONOMY

Soil Taxonomy has enhanced soil-use interpretations because of the many soil-engineering and soil-plant relations interwoven throughout the system. The diagnostic horizon encompasses both the effect of soil genesis and, indirectly, the impact on soil behavior. The most precise predictions are made at the phase level of the soil series. These units are more precise because they are based on additional criteria such as slope, surface texture, and soil temperature. The diagnostic horizons are used in the higher categories to define broad soil groups. The more exact quantitative definitions introduce a higher degree of standardization in the A, B, C horizon concept than that found in former systems. This avoids subjectivity in definition and allows for greater consistency and for easier comparison between soils of different areas. The system is also better equipped to facilitate the transfer of research information from one area to another. All of this leads to increased effectiveness in using soil surveys for planning and building better road systems and other engineering works.

SELECTION OF CRITERIA

Diagnostic horizons are used as criteria in Soil Taxonomy because they are the result of the soil weathering process. Soil weathering encompasses those processes that produce the natural soil in situ. The natural soil is born as soon as earthy material is exposed to the soil-forming elements. The effects vary. Water moving freely through calcareous soil material begins to move soluble calcium carbonates out of the soil system. Figure 1 shows how pH or soil acidity changes with depth in three soils in Tensas Parish, Louisiana (3). The oldest soil, Dundee silt loam, is estimated to be 3000 years old and has the lowest pH. It has a B horizon that meets the requirements of an argillic horizon. The fresh alluvial deposits have no reduction, and the Commerce silt loam is in between in age and has experienced some leaching. The B horizon in the Commerce soil classifies as a cambic horizon. No clay

Figure 1. pH of soils of differing ages.



translocation is noted in these soils.

The process of soil weathering becomes much more complex with time. Rocks weather to release minerals, organic matter is added, plant roots penetrate deeper, and minerals and salts are translocated from one part of the soil profile to another and sometimes moved completely out of the soil system. The processes that go on in soils can seldom be seen or measured (4), but the effects of at least some of the dominant processes can. Some processes produce horizons whereas others tend to prevent horizon formation. For example, downward-moving water carries suspended or dissolved materials and tends to produce B horizons; opposing processes of churning and "self-swallowing," prominent in the expansive Vertisols (4), tend to mix horizons (the absence of B horizons is definitive of Vertisols).

Simonson (5) has observed that a very important lesson in the development of soil classification in the United States is that soil characteristics exist in combinations. For example, strongly leached A-2 horizons occur with clayey B horizons. The diagnostic horizons are used to produce groupings in which the same present or past soil-forming processes have been dominant. Many of the diagnostic horizons take the form of A, B, and C horizons but with more precise definitions. For example, Spodosols are defined as having spodic horizons (horizons that have accumulated aluminum, iron, and organic matter), Alfisols have accumulations of clays and are named argillic horizons, and Mollisols have a mollic epipedon (surface horizon) that is dark-colored and high in organic matter. Calciustolls are recognized at the great group level by having calcic horizons. Although these classes of soils are too broad to correlate with American Association of State Highway Officials (AASHO) or Unified Soil Classification units, they do lead to groups of soils that can be correlated at the family and series levels.

The table below gives the syllables in great group names that indicate their respective diagnostic horizons.

Great Group	Syllable	Horizon
Argiabolls	arg	Argillic
Natralbolls	natr	Natric
Argiaquolls	arg	Argillic
Calciaquolls	calc	Calcic
Hapoloborolls	hapl	Minimum
Durixerolls	dur	Duripan
Fragiudalfs	frag	Fragipan

CHARACTERISTICS AND SIGNIFICANCE OF DIAGNOSTIC HORIZONS

Soil horizons have a unique relation to the engineering behavior of soils. The subsurface soil horizon is usually exposed by excavation during road construction. It may serve as the subbase or subgrade of the road, it has great influence on the design criteria and behavior of a road bank, and its nature is of value in estimating costs of excavations and cutting.

Most diagnostic horizons are subsurface horizons, but a few surface horizons, or epipedons, are used. The mollic epipedon is an important surface horizon because it is identified with some of the most productive soils in the world. It includes the A and B horizons of many of the prairie soils. The mollic epipedon is dark-colored, high in organic matter, and usually thicker than 18 cm (7 in) and friable. Other important surface horizons are the umbric epipedons, which are similar to mollic epipedons but have a lower base saturation and consist mostly of the A-1 horizons of timbered swamps in the southeastern United States, and the histic epipedons, which are thin surface horizons of peat or muck that occur in marshy and swampy areas.

These surface horizons are high in organic matter, which results in an engineering behavior in many that is equivalent to that of the A-7 or OH and OL soils of the AASHTO or Unified Soil Classification units. The mollic and umbric horizons are not always saturated with water but have received enough moisture to support luxuriant plant growth. The histic epipedon is saturated with water most of the time, has very high compressibility, subsides when drained, and classifies as OH or OL soil. The light-colored A horizons developed under forest vegetation are named ochric epipedons and are low in organic matter.

Most soil horizons that occur below the surface of the soil are considered B horizons and are closely related to the genesis of the soil. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused by soil-forming factors, such as an accumulation of clay, humus, sesquioxides, or some combination of these or a blocky structure, redder colors than the A horizon, or some combination of these.

An argillic horizon, which is an illuvial horizon in which clays have accumulated, is a very common soil horizon that occurs in many parts of the United States. The major soil orders Alfisols and Ultisols are characterized by argillic horizons. An argillic horizon is formed by clay moving from one horizon to another or from one point to another within a horizon. The clay is carried by water from the surface and near-surface horizons and is deposited on surfaces of soil aggregates or sand grains as the mixture dries. This means that a substantial amount of water has moved through the soil. Soils with argillic horizons occur in warm climates that have enough rainfall for effective leaching. The use of this horizon at a higher categorical level in the system has produced groupings of soils that have the largest number of common properties important to the use of the soil. These horizons are usually more clayey than any other part of the soil. Figure 2 shows the distribution of clay with depth in a typical Alfisol, and Figure 3 shows the clay distribution of an argillic horizon in a much older Ultisol. The clays in argillic horizons are also typically finer and more active than clays in other portions of a soil profile. Argillic horizons that contain high proportions of the more active 2:1 lattice clays make poor subbase or subgrade materials. In sandy soils, however, argillic horizons have enough clay for the binding necessary in good subbase materials.

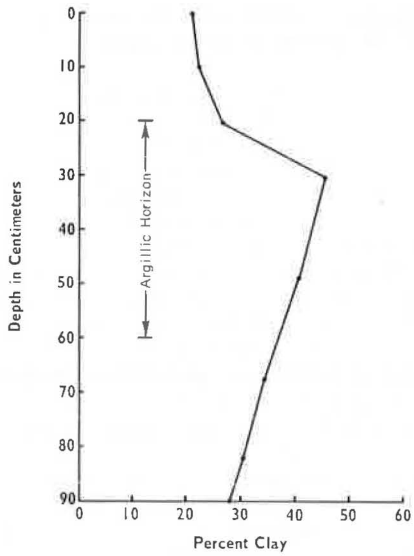


Figure 2. Distribution of clay with depth in typical Alfisol.

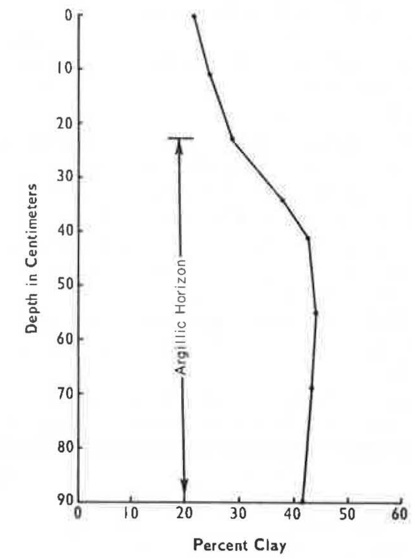


Figure 3. Distribution of clay with depth in typical Ultisol.

The natric horizon—a special kind of argillic horizon that is high in sodium—is another important B soil horizon, mainly because of its poor physical properties. Soils with natric horizons are more common in the more arid states of the Great Plains but also occur along the southern Mississippi River Valley. The material in these soil horizons is poorly suited for road base material. Soils with these horizons usually test A-7, have low traffic-supporting capacity, and are trouble spots in the location of road systems.

The spodic horizon is an accumulation of organic matter and aluminum with or without iron, formed by downward-moving water that carries the organic material. These B horizons, formed under pine forests, occur in both warm and cold climates. The material is usually precipitated at the upper limits of a fluctuating water table and is very active. It has high exchange capacity, large surface area, and high water retention when not cemented. The material in the less sandy spodic horizons behaves much like OM or OL soil material and makes very poor subgrade material.

Cambic horizons are also subsurface horizons that are altered through soil weathering. These too are identified as B horizons, but they have a sandy loam or finer texture and are less altered than the diagnostic horizons discussed above. There is no evidence of clay translocation in cambic horizons. The evidence of alteration includes the soil structure; chemical changes caused by wetness, such as dull grey colors and mottling; movement of carbonates; and browner or redder colors than those found in the parent material. The pH curve of Commerce silt loam in Figure 1 is an example of a slightly weathered cambic horizon. The cambic horizon is indicative of a soil that exhibits very little alteration. Such a horizon may occur in a young soil that has not been in place very long or in a soil on a steep slope or in any other location where the natural process of clay translocation is preempted by other forces such as soil erosion and soil creep. The engineering behavior of the soil material in cambic horizons is very similar to that of the parent materials. These horizons may range in the AASHO classification from A-2 to A-6.

The oxic horizons, which are the B horizons of soils common in tropical regions, are mineral subsurface horizons in an advanced stage of weathering. They are a mixture of hydrated oxides of iron or aluminum or both and variable amounts of 1:1 lattice clays. Oxic horizons generally are found in soils of very old, stable, geomorphic surfaces. Whatever the materials, the great age of the oxic horizon has allowed time for so much soil weathering that the horizon retains almost no vestige of the original rock structure. Analyzing the particle-size distribution in an oxic horizon is difficult: Some oxic horizons have silt- and sand-size aggregates of clay that are not easily dispersed but that contribute to the cation exchange capacity and other aspects of behavior common to the clays. The materials in oxic horizons are stable and very porous in place and have high bearing capacity. Once disturbed, however, they behave much differently: They are difficult to compact, unstable, and highly susceptible to slippage and other movement. The normal engineering tests on these soils can be misleading. The tests may indicate sands and silts with little clay, but the behavior may be like that of fat clays. It is not possible to indicate the engineering properties accurately from the engineering classification. Many of the tests show a CH classification in the laboratory, but in situ behavior of the soils is more like that in an SM classification.

The duripan is a subsurface horizon cemented by silica. Duripans may also be cemented by iron oxides and calcium carbonates. These horizons are always brittle, even after wetting, and they are common in the arid and semiarid climates of the western United States. They are difficult to sample and to test in the laboratory. When in place and not disturbed, they behave like rock, but they are rippable and, when properly crushed, make good road base material.

A fragipan is another kind of brittle subsurface horizon. Fragipans, identified as B and C horizons, have high bulk density and loamy texture and are seemingly cemented when dry. They are very difficult to excavate. When they are moist, the material is softer and easier to crush. Soils with these horizons occur in the more humid sections of the United States. The significance of these soil horizons is that they are nearly impervious and, because they create excessive wetness during rainy periods, they can cause problems in highway performance. Water stands above the pan in a level soil and moves laterally along the top of the pan if the soil is sloping, creating seep lines in road cuts. In the colder regions soils with these horizons are very susceptible to frost heaving.

The calcic horizon, another form of B horizon, is an accumulation of calcium carbonate or of calcium and magnesium carbonate. This accumulation may occur in the mollic epipedon, an argillic or natric horizon, or a duripan. These horizons occur mostly in soils of arid and semiarid regions and indicate the depth of water movement. In soils rich in carbonates, the calcic horizon tends in time to become plugged with carbonates and cemented into a hard, massive, continuous horizon that is called petrocalcic. In engineering behavior this horizon simulates hard country rock.

The diagnostic horizons may not have a direct bearing on soil behavior, but they are important building blocks of the system. They are used to group together soils that have something in common that is eventually expressed in the unique behavior of the soil. For example, argillic horizons indicate an accumulation of transported clay; they do not reflect kind and amount of clay, which strongly influence engineering behavior. Kind and amount of clay are reflected in the lower categories of the system, namely, family and series. Thus, there are many kinds of soils that have different engineering properties but that all have argillic horizons.

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Soil Moisture and Temperature Regimes in Soil Taxonomy

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Soil moisture and temperature regimes have been used as criteria for the classification of soils in the United States since the National Cooperative Soil Survey adopted Soil Taxonomy in 1965. The quantitative criteria used to define soil moisture regimes are based on the depth, probable duration, and seasonality of soil saturation and vegetation-restricting soil dryness. Soils with morphological evidence of frequent surface flooding are identified. Soils with extremely low bearing strength because of the interaction of their mineral and organic components with ambient high moisture contents are also taxonomically identified. Criteria for soil temperature regimes encompass the mean annual soil temperature and the amplitude of the change in soil temperature from summer to winter. Permafrost conditions are identified. Limited ranges for each of these soil temperature and moisture properties are defined and readily identified by connotative formative elements in the formal taxonomic name of each soil classified in modern soil surveys.

Historically, the study of temperature and moisture conditions affecting plant growth has been ascribed to the science of climatology or meteorology. Earlier, and some current, attempts to classify soils did not deal directly with soil temperature or moisture content except as they related to the chemical or mineralogical properties of soil. Soil scientists have recognized since the late 1800s that temperature and moisture regimes are closely related to soil properties. In 1965, the U.S. National Cooperative Soil Survey officially began to use direct criteria of soil moisture and temperature in its taxonomic criteria. Although this was a break with the long-standing tradition of not using soil moisture and temperature data for classification, it could be logically argued that a given soil, or given site, had distinct temperature and moisture regimes. Even though these factors were closely related to climatic conditions, the relation was no more indirect than, for example, the association of sandy soils to sandy parent materials, i.e., sandstones and sandy alluvial sediments. Furthermore, soil temperature and moisture could be measured. It was well known that these parameters of a soil varied with time of day and from day to day, season to season, and year to year. It was thus apparent that the use of soil temperature and moisture data in a soil taxonomic system would require criteria based on absolute ranges and probability (3).

One of the roles of the National Cooperative Soil Survey is to provide an inventory of the possible uses of land in the United States. Because much of our land is used for the growth of food and fiber, the soil moisture and temperature criteria used to classify the soil must have some direct interpretation for the growth of plants. Much of our land is also used for buildings and roads, and moisture and temperature conditions at any given site are an integral part of the planning for such condition (1). Flooding, bearing strength, and permafrost are some of the features of direct concern.

SOIL TEMPERATURE CRITERIA

Temperatures near the surface of the soil fluctuate diurnally, seasonally, with the amount and type of plant cover and the amount of water present in the soil. The magnitude of the fluctuations decreases with depth. However, at a given site, the mean annual temperatures at all soil depths, and even below the soil profile, differ only slightly (6). The mean annual soil temperature (MAST) is related most directly to the mean annual air temperature. Daily temperature variations are detect-